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U. S. S. *CASSIN* AND *CUMMINGS*.

DESCRIPTION AND TRIAL PERFORMANCE.

BY HENDERSON B. GREGORY, ASSOCIATE.

The Naval Bill, approved March 4, 1911, authorized the construction of eight torpedo-boat destroyers, Nos. 43 to 50, inclusive. The *Cassin* and *Cummings* are Nos. 43 and 44, respectively, of this lot.

They are twin-screw vessels fitted with a combination of Parsons turbines and reciprocating engine and designed for a speed of 29 knots, at a trial displacement of 1,010 tons, with the main turbines alone developing 16,000 shaft horsepower. They were built under contract by the Bath Iron Works, Limited, of Bath, Me. The contracts were signed September 6, 1911, the price being $761,500.00 for each vessel, and the time of construction twenty-four months.

PRINCIPAL HULL DIMENSIONS.

Length on L.W.L., feet and inches	300–0
overall, feet and inches	305–3
Breadth, extreme, at L.W.L., feet and inches	30–3
Ratio of length to beam (L.W.L.)	9.92

Draught to L.W.L., feet and inches	9–3
Displacement corresponding, tons	1,010
per inch at L.W.L., tons	14.25
Area immersed midship section, square feet	190
Coefficient of fineness, block	0.42

GENERAL DESCRIPTION OF HULL.

The hulls are of steel, galvanized in all parts below the water line, except structure wholly within the fuel-oil tanks.

Each vessel has the customary raised forecastle, which is carried aft to frame No. 46. On the forecastle deck are located the anchors, capstan, and pilot house, with bridge above. Above the bridge is a searchlight platform on which is mounted one searchlight.

The main deck is a weather deck aft of frame No. 46. On this deck and under the forecastle are located a small store room, lamp and windlass-engine room, wardroom officers' quarters, pantry and ship's galley. Aft there is a deck house in which are located the crew's water closets and washroom and wireless room. There are two masts fitted with signal yards and wireless outfit.

The berth deck is in two parts, extending from the stem to frame No. 48 and from frame No. 134 aft, the space between being interrupted by the deep fuel-oil tanks, cofferdam and machinery compartments. On this deck forward are located store rooms, paints and oils room and crew's quarters, and aft are located crew's quarters and store rooms.

In the hold, from forward aft, are the forward trimming tanks, chain lockers, stores, fuel-oil tanks, magazines and handling rooms, fuel-oil tanks, cofferdam (extending to the main deck and arranged to be used as a reserve-feed tank), boiler, engine and auxiliary machinery rooms, fuel-oil tanks, magazine and handling rooms, fuel-oil tanks and the after trimming tanks. There is a reserve-feed tank, built in the ship's structure, in the forward end of the engine room, and similarly constructed fresh-water tanks in the forward fire-room outboard of boiler No. 2, port and starboard. There is

also an engineer's store room in each fireroom, and a small coal bunker for galley purposes in the port forward corner of the forward fireroom.

BATTERY.

The battery consists of five 4-inch rapid-fire guns, one on the forecastle, commanding ahead and broadside fire, two on the main deck forward, port and starboard, at break of forecastle, one on the main-deck center line abaft of deck house, and the other on the main-deck center line well aft.

The torpedo outfit consists of four 5.2-m. by 45-cm. twin torpedo tubes mounted on the main deck; two abaft of the engine hatch at frame No. 118, port and starboard, one at frame No. 95, starboard, and one at frame No. 76, port.

There is a four-stage Ingersoll-Rand air compressor for the torpedoes, located in the auxiliary machinery room. Its capacity is 20 cubic feet of air at 2,500 pounds per square inch per minute. The steam cylinder is 8 inches in diameter and the compressor cylinders are $9\frac{1}{4}$, $4\frac{3}{4}$, $3\frac{1}{8}$ and $1\frac{1}{4}$ inches in diameter, respectively, for the four stages, with a common stroke of 5 inches. No accumulator is fitted.

BOATS CARRIED.

The following small boats are carried in davits at the vessel's side:

One 20-foot power dory;
Two 20-foot whale boats;
One 14-foot wherry.

ANCHOR WINDLASS.

The anchor windlass is located on the main deck at frame No. 12. It is of the Hyde Steam Windlass Co.'s vertical type, with engine of the following principal dimensions:

Number of cylinders	2
Diameter of cylinders, each, inches	$4\frac{1}{2}$
Stroke, inches	4

STEERING ENGINE AND GEAR.

There are three steering stations: (1) The pilot house, fitted with combined steam and hand gear; (2) top of the pilot house, steam gear only; (3) the hand gear on the main deck aft. The steering engine, of the Hyde Steam Windlass Co.'s horizontal type, is located in the pilot house, and is of the following principal dimensions:

Number of cylinders	2
Diameter of cylinders, each, inches	6½
Stroke, inches	5½

FIRE MAIN.

The fire main extends throughout the machinery space on the starboard side close under the main deck beams. It is 2½ inches in diameter, which size is carried forward to frame No. 38 and aft to frame No. 137 in the crew's spaces. The main is supplied by two fire and bilge pumps, located in the auxiliary machinery room, the pump connections being the full size of the main. Branches for the various fire plugs are taken off the main at convenient locations. All fire plugs are 1½ inches in diameter and located as follows:

Plug No.	Location.
1.	Crew's quarters, berth deck, frame No. 25, port.
2.	Crew's quarters, berth deck, frame No. 144, starboard.
3.	Main deck, frame No. 46, starboard.
4.	Main deck, frame No. 78, starboard side of smoke pipe No. 3.
5.	Main deck, frame No. 107, starboard side of engine hatch.
6.	Main deck, frame No. 136, starboard of center line.
7.	Forecastle deck, frame No. 37, port of center line.

In addition to the regular fire plugs above enumerated there is a 1½-inch hose valve on the discharge manifold of each fire and bilge pump.

Forward and aft there are 2-inch connections from the fire main for magazine flooding and sprinkling.

A 1-inch connection is taken off the fire main aft for flushing out the stern-tube bearings, a full size branch being led to each bearing.

FLUSHING SYSTEM.

The flushing system is taken off the fire main direct. There is a 1½-inch connection forward supplying the officers' water closet and ship's galley, and one of 2½ inches aft for the crew's water closets and wash room.

FRESH-WATER SYSTEM.

Fresh water is carried in the ship's tanks, located in the forward fireroom, port and starboard, and having a combined capacity of about 3,920 gallons. The tanks have two 2½-inch filling connections, port and starboard, respectively, fitted with hose valves at the ship's sides. There is also a 1¼-inch filling connection from the distilling apparatus to the starboard tank.

Located on the forecastle deck, immediately abaft the pilot house, is a small gravity tank of 50 gallons capacity for supplying the galley and officers' showers. The tank is fitted with steam coil to prevent freezing in cold weather. A hand pump is provided in the galley for filling this tank.

DRAINAGE SYSTEM.

A main drain is led throughout the machinery spaces and connected to the fire and bilge pumps by suctions the full size of the main. Macomb strainers are fitted in these suctions close to the pumps. The main is 4 inches outside diameter in the auxiliary room, engine room and after fireroom, reducing to 2½ inches outside diameter in the forward fireroom forward of the bilge-suction connection. There is a full size bilge suction connection from the main drain in each fireroom and auxiliary machinery room, and two in the engine room, fitted with plate strainers at the bilge ends.

For draining compartments outside of the machinery spaces there are 2½-inch outside diameter branches leading forward

and aft and fitted with connections to the various compartments requiring drainage and the trimming tanks.

In addition to the drainage system proper, the engine room is provided with a 7-inch independent bilge-suction connection to the circulating pump for emergency use.

VENTILATION.

The ventilation of all living spaces, etc., is by natural means, except in the boiler rooms, which are ventilated by the forced-draft blowers.

HEATING SYSTEM.

The usual heating system, with brass-pipe coil radiators, is installed. Steam for the quarters forward is taken off the auxiliary steam line in the forward boiler room, and that for the after compartments from the auxiliary steam line in the engine room.

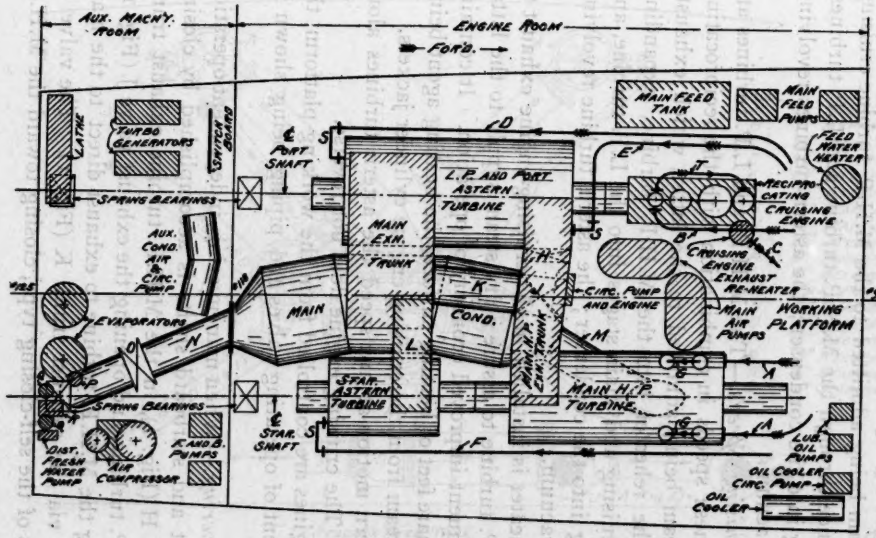
MAIN ENGINES.

The main propulsive machinery comprises an installation of Parsons turbines in combination with a small reciprocating engine, for use at cruising speeds up to 15½ to 16 knots.

The turbines are designed to run at 550 r.p.m. when developing 16,000 S.H.P., and the cruising engine is designed to develop 700 I.H.P. at 270 r.p.m., corresponding to the speeds noted in preceding paragraph.

The engines are arranged on two lines of shafting as shown in Fig. 1, which provides one ahead and one astern turbine on each shaft, the L.P. turbine including an astern turbine in the after end of its casing. The cruising engine is on the port shaft forward of the L.P. turbine, and fitted with clutch coupling for disconnecting from the turbine shaft when not in use. In addition to the cruising engine, two cruising stages are provided in the M.H.P. turbine casing, which are bypassed at the higher speeds.

For ahead motion the starboard shaft is driven by the M.H.P. turbine, and the port shaft by the L.P. ahead turbine,



MARK	DESCRIPTION
A	9½" STEAM TO M.H.P. TURBINE.
B	5" " " CRUISING ENG.
C	8" CRUISING ENG. EXHAUST TO M.H.P. TURBINE.
D	6" PORT ASTERN STEAM.
E	7" " AHEAD MANEUVERING STEAM.
F	6" STAR. ASTERN STEAM.
G	9" M.H.P. TURBINE BYPASSES AROUND CRUISING STAGES.
H	SELF-CLOSING VALVE (CLOSING TOWARD M.H.P. TURBINE).
J	30" VALVE M.H.P. TUR. DIRECT EXHAUST TO MAIN CONDENSER.
K	30" M.H.P. TUR. DIRECT EXHAUST TRUNK TO MAIN CONDENSER.
L	STAR. ASTERN TURBINE EXHAUST TRUNK.
M	28" MAIN INJECTION PIPE.
N	28" " OUTB'D. DEL. PIPE.
O	28" " " " VALVE.
P	EVAPORATOR FEED HEATER.
Q	DISTILLERS.
R	EVAPORATOR FEED PUMP.
S	STEAM STRAINERS.
T	CRUISING ENG. REC'R PIPE.

NOTE: FOR ARR'T OF PIPES AND VALVES AT WORKING PLATFORM SEE FIG. 2.

DIAGRAM ARRANGEMENT OF MACHINERY AND PIPING IN ENGINE AND AUX. MACH'Y ROOMS. U.S.S. CASSIN AND U.S.S. CUMMINGS.

FIG. 1.

alone or in combination with the cruising engine, as described in the following paragraphs:

Full Speed Ahead.—The two ahead turbines are used for this purpose, steam being admitted to the M.H.P. turbine, bypassing cruising stages, and expanded through the L.P. turbine into the condenser. Under this condition the astern turbines revolve idly in a vacuum, which is maintained through the exhaust connections to the condenser.

High Cruising Speeds.—Two turbines are used at these speeds, steam being admitted to the M.H.P. turbine cruising stages, thence through the M.H.P. turbine and L.P. turbines, exhausting into the condenser; the astern turbines revolving idly in a vacuum.

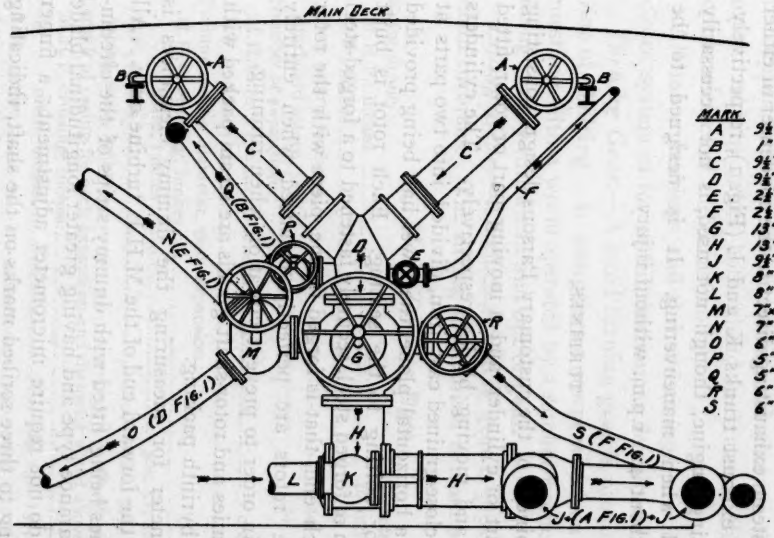
Low Cruising Speeds.—The M.H.P. and L.P. turbines are used for these speeds in combination with the reciprocating engine, steam being admitted to the latter, which exhausts through the reheater into the M.H.P. turbine, expanding through cruising and main stages into the L.P. turbine, and exhausting into the condenser; the astern turbine revolving idly in a vacuum.

The reheater is installed in the cruising-engine exhaust to the M.H.P. turbine to assure a dry steam supply to the latter and consequent improved economy of operation. It contains 112.91 square feet of heating surface, the heating agent being exhaust steam from the cruising-engine cylinder jackets.

For astern motion at any speed the astern turbines alone are used. The cruising engine does not reverse.

The engines are controlled from the working platform, the arrangement of operating valves and piping being shown in Fig. 2.

Maneuvering.—When maneuvering, independent operation of the port and starboard shafts is accomplished by closing the valve H (Fig. 1), in the M.H.P. turbine exhaust trunk to the L.P. turbine, and opening the exhaust valve J (Fig. 1), permitting the M.H.P. turbine to exhaust direct to the main condenser via the exhaust trunk K (Fig. 1). The valve H (Fig. 1) is of the self-closing type, closing toward the M.H.P.



SECTION AT FRAME #100 LOOKING FORWARD.

FIG. 2.

MARK	DESCRIPTION
A	9½" MAIN STEAM STOP VALVE
B	1" BYPASS
C	9½" MAIN STEAM PIPE
D	9½" x 3½" x 13" EXPANSION JOINT
E	2½" BLEEDER VALVE
F	2½" BLEEDER PIPE
G	13" MAIN THROTTLE VALVE
H	13" MAIN STEAM STRAINER
J	9½" STEAM TO M.H.P. TURBINE
K	8" RECIPROCATING ENGINE EXHAUST VALVE
L	8" RECIPROCATING ENGINE EXHAUST PIPE.
M	7" x 6" PORT MANEUVERING VALVE
N	7" PORT AHEAD MANEUVERING STEAM
O	6" PORT ASTERN MANEUVERING STEAM
P	5" RECIPROCATING ENGINE THROTTLE VALVE
Q	5" RECIPROCATING ENGINE STEAM PIPE
R	6" STARBOARD ASTERN MANEUVERING VALVE
S	6" STARBOARD ASTERN MANEUVERING STEAM

ARRANGEMENT OF VALVES AND PIPING AT WORKING PLATFORM U.S.S. CASSIN AND U.S.S. CUMMINS

turbine, in order to prevent a back flow of steam to the latter, should the port ahead maneuvering steam be suddenly turned into the L.P. turbine. This valve is also arranged to be locked shut, thus securing positive isolation of the port and starboard turbines from each other. Each shaft can then be operated independently, either ahead or astern, as follows: The port shaft is controlled by the maneuvering valve M (Fig. 2), which admits steam to either the L.P. or astern turbines as desired. The starboard shaft is correspondingly controlled by the main throttle valve G (Fig. 2) for ahead motion, and the maneuvering valve R (Fig. 2) for astern motion, the steam exhausting direct to the condenser in either case, via the exhaust trunks K and L (Fig. 1), respectively.

The cruising engine, though not used, is not necessarily disconnected when maneuvering. It is designed to be dragged at about 400 r.p.m. without injury.

TURBINES.

Each turbine is of the customary Parsons design, consisting of a fixed part or cylinder, and a moving part or rotor, fitted with guide and moving blades respectively. The cylinders are of hard close-grained cast iron, divided into two parts at the axis on a horizontal plane, the lower half being provided with feet for bolting to the seating. Each rotor is built up of a drum of forged steel, securely fastened to a forged-steel wheel at each end, that is forged in one piece with the rotor shaft. The rotors are perfectly balanced when entirely completed, in order to prevent vibration when running.

The dummies and rotor-shaft glands are steam packed with the usual labyrinth packing.

A micrometer for measuring the dummy clearances is provided at the forward end of the M.H.P. turbine only. All other turbines being fitted with dummy strips of the circumferential clearance type and having greater longitudinal blade clearances, do not require micrometer adjustment; a finger plate pointing to three scribed marks on the shaft, indicating

the mean and extreme safe fore and aft positions of the moving parts, alone being necessary for the other turbines.

Main Bearings.—There is a main bearing at each end of each turbine for supporting the rotor. All bearings consist of a pedestal cast with the turbine casing and fitted with bottom brass and cap.

Thrust Block.—The M.H.P. turbine and L.P. and astern turbine are provided with thrust blocks at the forward end, consisting of a number of brass rings, in halves, fitted into corresponding collars on the shaft. The lower half of the M.H.P. turbine thrust bearing is for taking the ahead and the upper half the astern thrust, and that on the L.P. and astern turbine takes both ahead and astern thrust on the entire surface of the thrust collars.

All main bearings and thrust bearings are fitted with a closed system of forced lubrication, as described elsewhere.

Turning Gear.—A hand turning gear is provided for each line of shafting. It comprises a worm wheel on each shaft, meshing with a worm operated by a ratchet wrench, the worm being readily thrown in and out of gear.

Lifting Gear.—An efficient lifting gear is provided for the main turbines. The lifting mechanism is hand operated.

Main Turbine Data.

	Diameter.	Length.
Rotor drums:		
M.H.P., inches	46 and 48	132⅛
L.P., inches	60	83 1⅝
Port astern, inches	44	76¼
Starboard astern, inches	44	56⅛
Number of expansions:		
M.H.P.	2 cruising, 6 main.	
L.P. and both astern	6 each.	
Turbine casing, diameter, each expansion:		
M.H.P. cruising, inches	47⅛ and 47⅞	
main, inches	50⅛, 51, 52½, 54, 56½, 60	
L.P., inches	70½, 75, four of 81	
Astern, each, inches	44, 46, 48, three of 49½	
Length of casing for each expansion and diameter noted above:		
M.H.P. cruising, inches	9⅛, 13 1⁄16	
main, inches	12½, 13½, 13⅞, 14⅛, 15⅛, 18 9⁄16	
L.P., inches	10½, 12, 13⅞, 15, 19½, 10 5⁄16	
Astern, each, inches	7⅞, 9⅛, 9⅛, 8¼, 7½, 4	

Rows of blading for each expansion:	
M.H.P., cruising, each	11
main	four of 10 and two of 9
L.P.	five of 6 and one of 3
Astern, each	three of 7, one each of 5, 4 and 2
Length of blades for each expansion:	
M.H.P., cruising inch	¼ and $\frac{15}{16}$
main, inches	$1\frac{1}{16}$, $1\frac{1}{4}$, $2\frac{1}{8}$, 3, $4\frac{1}{4}$, 6
L.P., inches	$5\frac{1}{4}$, $7\frac{1}{2}$, four of $10\frac{1}{2}$
Astern, each, inches	½, 1, 2, three of $2\frac{1}{4}$

Rotor shafts and bearings:	Length of bearing.	Diameter at bearing.	Diameter of axial hole.
M.H.P., inches	10	10	5
L.P., inches	16	10	5
Port astern, inches	16	10	5
Starboard astern, inches	10	10	5

Thrust bearings, each:	M.H.P.	L.P.
Collars on shaft, number	17	10
Thickness, inch	⅜	$0\frac{5}{8}$
Distance between, inch	$1\frac{3}{16}$	$0\frac{3}{4}$
Outside diameter, inches	$12\frac{1}{2}$	$12\frac{1}{2}$
Inside diameter, inches	$8\frac{1}{2}$	$8\frac{1}{2}$
Number of shoes, top	16	9
bottom	17	9

Cruising-Engine Data.

Type	Vertical, inverted, direct-acting, compound, jacketed,
Cylinder, H.P., diameter, inches	16
L.P., diameter, inches	24
Stroke, inches	18
Cranks, set at degrees	180

SHAFTING.

There are two lines of shafting, as indicated in Figure 1, of four sections each, consisting of two line shafts supported by three spring bearings, one stern-tube shaft supported by the two stern-tube bearings, and one propeller shaft supported by the strut bearing.

All stern-tube and strut bearings are lined with lignum vitae and the shafts are composition bushed at these bearings. The shafting within the stern tube is covered with a casing of seamless drawn brass tubing, shrunk on.

The inboard coupling consists of a collar secured to the stern-tube shaft by four keys. Forward of this collar are two thin half collars fitted into a groove turned in the end of the

shaft, to prevent the shaft from backing out, the whole being through bolted to the coupling disk on the line shaft.

The outboard coupling is of the ordinary sleeve type secured to the shaft by four feathers and two cross-keys each.

Shaft Data.

Line shafts, diameter, outside, inches	8¼
at journals, inches	8¾
axial hole, inches	5
Stern-tube shaft, diameter, outside, inches	8¼
axial hole, inches	5
Propeller shafts, diameter, outside, inches	8¼
axial hole, inches	5
Coupling disks, diameter, inches	15½
thickness, inches	1¾
Inboard coupling, diameter of collar, outside, inches	15½
inside, inches	9½
length of collar, inches	5½
thickness of half collars, inches	1½
Coupling bolts, number each coupling	8
diameter (taper) * at face of coupling, inches	1¾
Outboard coupling, length of sleeve, inches	32⅞
diameter of sleeve, outside, inches	12
Spring bearings, diameter, inches	8⅞
length, inches	12
Forward stern-tube bearings, diameter, inches	9⅝
length, inches	28
After stern-tube and strut bearings, diameter, inches	9⅝
length, inches	42

PROPELLERS.

There are two three-bladed propellers. The port propeller is left-hand and the starboard propeller is right-hand. The blades and hubs are of manganese bronze and cast in one piece. The blades are true-screw machined to pitch.

Propeller Data.

Diameter, feet and inches	7–4
Pitch, feet and inches	6–8
Ratio of pitch to diameter	0.909
Area, projected, square feet	25.375
helicoidal, square feet	28.69
disk, square feet	42.24
Ratio, projected, to disk	0.6
helicoidal, to disk	0.679

* Parallel bolts in inboard coupling.

MAIN CONDENSING APPARATUS.

Main Condenser.—There is one main condenser of circular section located on the center line of the vessel between the turbines. It is of the curved-tube type, with the tubes expanded in both tube sheets, which are bumped outward to a radius of ninety-five inches. The principal dimensions are as follows:

Diameter, end sections, inside, feet and inches	6–3½ to 6–0¼
middle section, inside, feet and inches	6–4
Thickness of shell, end sections, inch	0¼
middle section, inch	0 5/16
tube sheet, inches	1¼
Tubes, number	4,317
diameter, inch	0⅝
thickness, inch	0.049
mean length between tube sheets, feet and inches	15–3½
Cooling surface, square feet	10,800
Main exhaust nozzle, area through, square feet	30
Starboard astern turbine exhaust nozzle, area through, sq. feet	4.28
Diameter of air-pump suction, inches	17
circulating-water inlet and outlet, inches	28
auxiliary exhaust nozzle, inches	10
M.H.P. turbine exhaust nozzle, inches	30⅝
bleeder, inches	2½

MAIN AIR PUMP.*

Two Warren, vertical, twin, bucket, single-acting air pumps are provided for the main condenser. Each pump has a single steam cylinder 14 inches in diameter, and two water cylinders 28 inches in diameter each, with a common stroke of 18 inches.

CIRCULATING PUMP AND ENGINE.*

The condenser is provided with a small centrifugal circulating pump, driven by an independent single reciprocating engine, for use in port and when maneuvering. Under normal service conditions the circulating water is forced through the condenser by means of a scoop on the main injection, the circulating pump not being used. The principal dimensions of the pump and engine are as follows:

*See Table I.

Diameter of suction nozzle, inches	17¼
discharge nozzle, inches	17¼
impeller, inches	23
engine cylinder, inches	7
Stroke of engine, inches	5

VACUUM AUGMENTER.

The customary Parsons vacuum augmenting apparatus is provided, consisting of a small condenser of the curved-tube type, steam jet and water seal, connected to the main air-pump suction piping in the usual manner.

The augmenter condenser is of the following principal dimensions:

Diameter, inside, inches	22¾ and 21
Thickness of shell, inch	$0\frac{3}{16}$
Tubes, number	277
diameter, inch	0¾
thickness, inch	0.049
Mean distance between tube sheets, feet and inches	5–$6\frac{13}{16}$
Cooling surface, square feet	253
Diameter of augmenter connection, inches	14
air-pump suction, inches	14
circulating-water inlet and outlet, inches	4

FEED AND FILTER TANK.

A feed and filter tank of about 800 gallons gross capacity located in the port forward end of the engine room. The filter chamber is in the top of the tank, and so arranged that the entering water will flow over the top of a plate and leave through perforated plates in the bottom of the chamber after passing through the filtering material.

AUXILIARIES IN ENGINE AND AUXILIARY-MACHINERY ROOM.

*Auxiliary Condenser Air and Circulating Pump.**—There is an auxiliary condenser in the auxiliary-machinery room connected through the auxiliary exhaust line to all auxiliary machinery. It is of the curved-tube type with tubes rolled

*See Table I.

in both tube sheets. The condenser has a 6-inch × 8-inch × 8-inch × 7-inch Warren, horizontal, single, double-acting, combined air and circulating pump.

The condenser is of the following principal dimensions:

Diameter, inside, inches	22¼ and 21
Thickness of shell, inch	$0\frac{3}{16}$
Tubes, number	277
diameter, inch	$0\frac{5}{8}$
thickness, inch	0.049
Mean distance between tube sheets, feet and inches	$5\text{–}6\frac{3}{16}$
Cooling surface, square feet	253
Diameter auxiliary exhaust nozzle, inches	6
air-pump suction, inches	4
circulating water inlet and outlet, inches	4

*Main Feed Pump.**—Two Warren 15-inch × 10-inch × 16-inch main feed pumps of the vertical, double-acting, single type are located in the port forward corner of the engine room. The pumps have suctions from the main feed tanks and discharge to the boilers through the feed-water heater or by passes.

Feed-Water Heater.—There is a feed-water heater of the direct-flow type installed in the engine room, on the discharge side of both the main and auxiliary feed pumps. The heating agent is the exhaust steam, a back pressure being kept in the auxiliary exhaust line for this purpose by means of a spring relief valve at each condenser connection, opening toward the condenser. The principal dimensions of the heater is as follows:

Diameter of shell, inches	$23\frac{1}{2}$
Thickness of shell, inch	$0\frac{3}{16}$
Length between tube sheets, feet and inches	$7\text{–}2\frac{5}{8}$
Tubes, number	508
diameter, inch	$0\frac{5}{8}$
thickness, inch	0.049
Heating surface, square feet	600
Diameter of feed inlet and outlet, inches	6
auxiliary exhaust nozzle, inches	9
drain, inches	2

* See Table I.

*Fire and Bilge Pumps.**—Two Warren 7-inch × 7-inch × 12-inch vertical, double-acting, single, fire and bilge pumps are provided in the auxiliary machinery room. They are arranged to draw from the drainage system and sea, and discharge to the fire main and overboard.

Forced-Lubrication System.—The main bearings, thrust bearings and circulating-pump engine are provided with forced lubrication.

The system comprises two oil pumps,* one oil cooler of 202.33 square feet of cooling surface, one oil-cooler circulating pump,* one oil drain tank of 200 gallons capacity, an oil-settling tank of similar capacity and the necessary piping and fittings.

The system functions as follows: The oil pumps draw oil from the drain tank and deliver it via the oil cooler to the various parts to be lubricated at a pressure of about 15 pounds. Macomb strainers are fitted in the pump suctions and a bypass arranged around the oil cooler. After the oil has passed through the bearings it is caught in troughs formed in the bearings bases and drained by gravity back to the drain tank, whence the cycle is repeated.

Lock cocks are fitted at each bearing for regulating the supply, and sight glasses for observing the oil flow are fitted in the drain from each bearing. A thermometer is also fitted at each sight glass to show the temperature of the oil leaving the bearings.

The oil pumps also discharge to a settling tank through a branch off the main discharge. The tank is provided with a steam coil to assist in settling the oil, and is drained back into the system by gravity, or drawn off by the pumps, a Macomb strainer being fitted in the connection next to the tank.

BOILERS.

There are four oil-burning Normand water-tube boilers, arranged in pairs in two separate compartments as shown in Fig. 3. They are designed to run the entire machinery plant

* See Table I.

at full power, with an average air pressure in the firerooms of about five inches of water.

Each boiler has an independent smoke pipe 34 feet 6 inches high above the base line of the vessel.

TABLE I.

PUMPS AND PUMP CONNECTIONS.

No.	Pumps	Size (Ins.)	Type	Suction Pipes		Discharge Pipes		Location
				Ins.	From—	Ins.	To—	
2	Main Air.	1-14x2-28 x18	Twin, vertical, bucket, single-acting.	11	Condenser, through nat. air seal.	10	Feed Tank.	Eng. Room
1	Circulating.	28-Dia. of runner 7x5 Eng.	Vertical, single engine; centrifugal pump.	17½ 7	Sea. Bilge.	17½	Main Condenser.	Eng. Room
2	Main Feed.	15x10x16	Vertical, piston, double-acting, single.	5½ 5½	Feed suction pipe and reserve feed tanks. Air pump suction.	4	Main feed discharge.	Eng. Room
2	Aux. Feed.	15x10x16	Vertical, piston, double-acting, single.	5½ 1½	Feed suction pipe and reserve feed tanks. Hose connection.	4 1½	Aux. feed. Hose connection.	One in each boiler room
2	Fire and Bilge.	7x7x12	Vertical, piston, double-acting, single.	4 4 1½	Sea. Drainage. Hose connection.	2½ 3½ 2 1½	Fire main. Overboard. Distiller. Hose connection.	Aux. room.
1	Aux. Air and Circulating.	6x8x8x7	Combined, horizontal, double-acting, single.	4 4	Aux. condenser. Sea.	3 4	Feed tanks. Aux. condenser.	Aux. room.
1	Evaporator Feed.	4½x6x6	Vertical, piston, double-acting, single.	2 1½	Sea. Distiller circulating water discharge.	1½	Evaporators.	Aux. room.
1	Distiller Fresh Water.	3½x4x4	Vertical, piston, double-acting, single.	1½	Distiller reservoir tank.	1½ 1½ 1½	Reserve feed tanks. Ship's tanks. Cofferdam.	Aux. room.
1	Oil Cooler Circulating.	7x7x12	Vertical, piston, double-acting, single.	3	Sea.	2½	Oil Cooler.	Eng. Room.
2	Lubricating Oil.	4½x6x6	Vertical, piston, double-acting, single.	3	Lubricating oil tank.	2½	Bearings	Eng. Room
4	Fuel-Oil Service.	5½x3½x8	Vertical, piston, double-acting, duplex.	2½ 2½	Oil storage tanks. Booster-pump discharge.	2	Burners.	Two in each boiler room.
2	Fuel-Oil Booster.	4½x6x6	Vertical, piston, double-acting, single.	3 2½	Storage tanks. Deck hose connection.	2½ 2½ 2½	Service-pump supply. Storage tanks. Deck hose connection.	One in each boiler room.

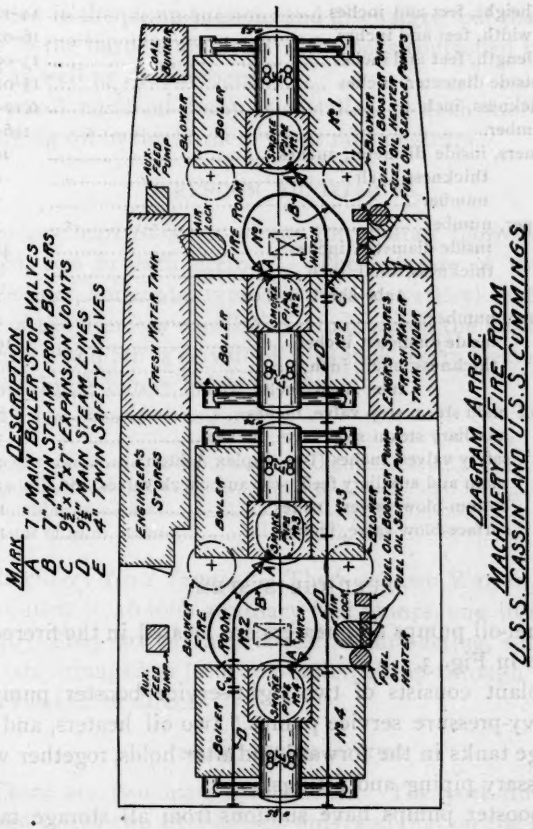


FIG. 3.

Data for one Boiler.

Working pressure, pounds	260
Number of furnaces	1
Furnace volume, cubic feet	520
Area through smoke pipe, square feet	19.2
Smoke pipe area / Furnace volume.	0.0368
Heating surface, square feet	5,377.34
Heating surface / Furnace volume	10.34
Oil burners, number	12
type	Modified Bureau of S. E.

External height, feet and inches	14–11 7/16
width, feet and inches	16–02 1/16
length, feet and inches	13–09 1/4
Tubes, outside diameter, inches	1 1/4–01 1/2
thickness, inch	0.12–0.109
number	116–1,594
Down-comers, inside diameter, inches	10
thickness, inch	0 8/8
number	2
Drum, upper, number	1
inside diameter, inches	44
thickness, shell, inch	0 1 1/16
tube sheet, inches	1 3/16
lower, number	2
inside diameter, inches	19
thickness, shell, inch	0 7/16
tube sheet, inch	0 4/4
Diameter of main steam stop valve, inches	7
auxiliary steam stop valve, inches	3
safety valves, inches (two duplex Ashton)	4
main and auxiliary feed, stop and check valves, ins.	3
bottom-blow valves, inches	1 1/2
surface-blow valve, inches	1 1/4

FUEL—OIL SYSTEM.

The fuel-oil pumps and heaters are located in the firerooms as shown in Fig. 3.

The plant consists of two light-service booster pumps,* four heavy-pressure service pumps,* two oil heaters, and the oil-storage tanks in the forward and after holds, together with the necessary piping and fittings.

The booster pumps have suctions from all storage tanks and the deck connection for taking on oil, and discharge to all storage tanks, service pumps' suctions and the deck connections.

The service pumps draw oil from the storage tanks and the booster pumps' discharges, and deliver it to the oil burners on the boilers, via the oil heaters or bypasses. The burners, twelve per boiler, of the slightly modified Bureau of Steam Engineering type, are mechanical atomizers. Strainers are

*See Table I.

provided in the pump suctions and discharges, and the supply pipes to the burners are fitted with cocks controlled from the deck as well as the firerooms.

A small hand oil pump is installed in each fireroom for supplying oil to the burners when raising steam.

FIREROOM AUXILIARIES.

Forced-Draft Blowers.—Four forced-draft blowers are installed, two in each fireroom. The fans are of the Keith single-inlet, horizontal type, mounted on vertical shafts in the base of the fireroom ventilators, from which the air supply is taken. Each fan is driven by a 24-inch Terry steam turbine located immediately below the fan.

The fan data is as follows:

Fan, diameter, inches	39
width, inches	11 1/16
number of blades	24
Diameter of inlet, inches	32 1/2

*Auxiliary Feed Pumps.**—There are two Warren, 15-inch × 10-inch × 16-inch auxiliary feed pumps, one in each fireroom. They are of the vertical, double-acting, single type and are arranged to feed any boiler, either through the feed-water heater or direct.

MAIN STEAM PIPING.

There are two main steam lines. The port line is connected to the two after boilers only, and that on the starboard side to the two forward boilers. The branches from the boilers are 7 inches in diameter each, and the lines proper are 9½ inches, uniting in the engine room into a common 13-inch casting at the working platform. Beyond the throttle valve the pipe again divides into two 9½-inch connections to the main H.P. turbine, and there is a 5-inch branch to the reciprocating cruising engine. A 2½-inch bleeder pipe to the main condenser is provided. The general arrangement of the main steam pipe is indicated in Figs. 1, 2 and 3.

*See Table I.

AUXILIARY STEAM PIPING.

There is a 3-inch stop valve on each boiler for supplying the auxiliary steam line, which leads throughout the machinery spaces with connections to the various auxiliaries and a branch forward to the deck machinery, forward heating system and galleys.

AUXILIARY EXHAUST PIPING.

An auxiliary exhaust pipe extends throughout the machinery spaces and elsewhere as required for the various auxiliaries. Connections are provided for direct exhaust into either the main or the auxiliary condenser, the feed-water heater, or into the atmosphere through the after escape pipe, at will. There are also connections for admitting exhaust steam into the L.P. turbine's steam belt and into the second and sixth expansions of the M.H.P. turbine when desired.

MAIN AND AUXILIARY FEED PIPING.

The main and auxiliary feed pumps take their suctions from the feed suction main, which extends from the bottom of the main feed tank to the auxiliary feed pump in the forward fireroom. The main is 8 inches in diameter in the engine room, decreasing in size to 7 inches in the after fireroom and $5\frac{1}{2}$ inches in the forward fireroom. The suction branches to all feed pumps are $5\frac{1}{2}$ inches in diameter. All feed pumps are arranged to feed any boiler via the feed heater or bypasses. The main feed line is 6 inches in diameter from the feed-water heater to first branch connection to boilers, decreasing in size to 5 to 4 inches, as it leads forward in the firerooms. The discharge from each pump is 4 inches and the branches to all boilers are 3 inches each. Each auxiliary feed pump also has a direct connection to all boilers, through a 4-inch independent main between the two firerooms.

INTERIOR COMMUNICATION.

The customary engine-room and fireroom telegraphs, gongs, telephones, voice tubes, etc., are fitted for transmitting orders and signaling to the machinery compartments and other parts of the vessel.

EVAPORATING AND DISTILLING APPARATUS.

The distilling apparatus is installed in the auxiliary machinery room, as indicated in Fig. 1.

There are two evaporators and two distillers, with their accessories, arranged to operate in single effect. The plant has a combined evaporator capacity of 3,750 gallons of water per twenty-four hours, that of the distillers being only 2,500 gallons.

Data for one Evaporator.

Type	Vertical, U-tubes.
Capacity per 24 hours, gallons.	1,875
Diameter, inside, inches	34
Thickness of shell, inch	$0\frac{3}{16}$
Height overall, feet and inches	6–0
Tubes, number	45
diameter, inches	$1\frac{1}{4}$
Thickness, inch	0.095
Heating surface, square feet	100
Diameter of steam nozzle, inches	2
vapor nozzle, inches	3
feed valve, inch	1
blow valve, inches	2

Data for one Distiller.

Type	Straight tube.
Capacity per 24 hours, gallons	1,250
Diameter inside, inches	$7\frac{1}{2}$
Thickness of shell (copper), inch	0.109
Length between tube sheets, feet and inches	2–$0\frac{3}{4}$
Tubes, number	61
diameter, inch	$0\frac{5}{8}$
thickness, inch	0.049
Cooling surface, square feet	20.6
Diameter of circulating-water inlet and outlet, inches	$1\frac{1}{4}$
vapor inlet, inches	$1\frac{1}{4}$
drain, inches	$1\frac{1}{4}$

MACHINE TOOLS.

For performing minor repairs one small motor-driven engine lathe, of 12 inches swing and 6-foot bed, is installed together with all the necessary tools and attachments. The driving motor is a 1¼ horsepower, direct-current, Reliance, adjustable-speed type, with speed ranges from 500 to 1,500 r.p.m.

ELECTRIC PLANT.

The dynamos are located in the auxiliary-machinery room (see Fig. 1). The installation consists of two horizontal, compound-wound, direct-current, 10-kilowatt, General Electric generators, each driven by a Curtis steam turbine. Each generator will deliver at normal load 80 ampères of current at 125 volts, when running 5,000 revolutions per minute.

TORSION METERS.

Each line of shafting is fitted with a Gary-Cummings torsionmeter for ascertaining the shaft horsepower of the main turbines.

TRIALS.

The contract required the following trials for each vessel:

(a) A progressive trial over a measured-mile course at Rockland, Me., for standardizing the screws, extending from maximum speed (at least 29 knots) down to a speed of 12 knots.

(b) A full-speed trial of four hours' duration in the open sea in deep water, at the highest speed attainable, the average for the four hours not to be less than 29 knots.

(c) A fuel-oil and water-consumption trial of four hours' duration in the open sea in deep water, at an average uniform speed of 24 knots, as nearly as possible. The trial to be conducted as nearly as possible to service cruising conditions.

(d) A fuel-oil and water-consumption trial at 15½ knots under conditions similar to the preceding trial, but with cruising engine connected and in use.

(e) An endurance trial of 24 hours in the open sea at an

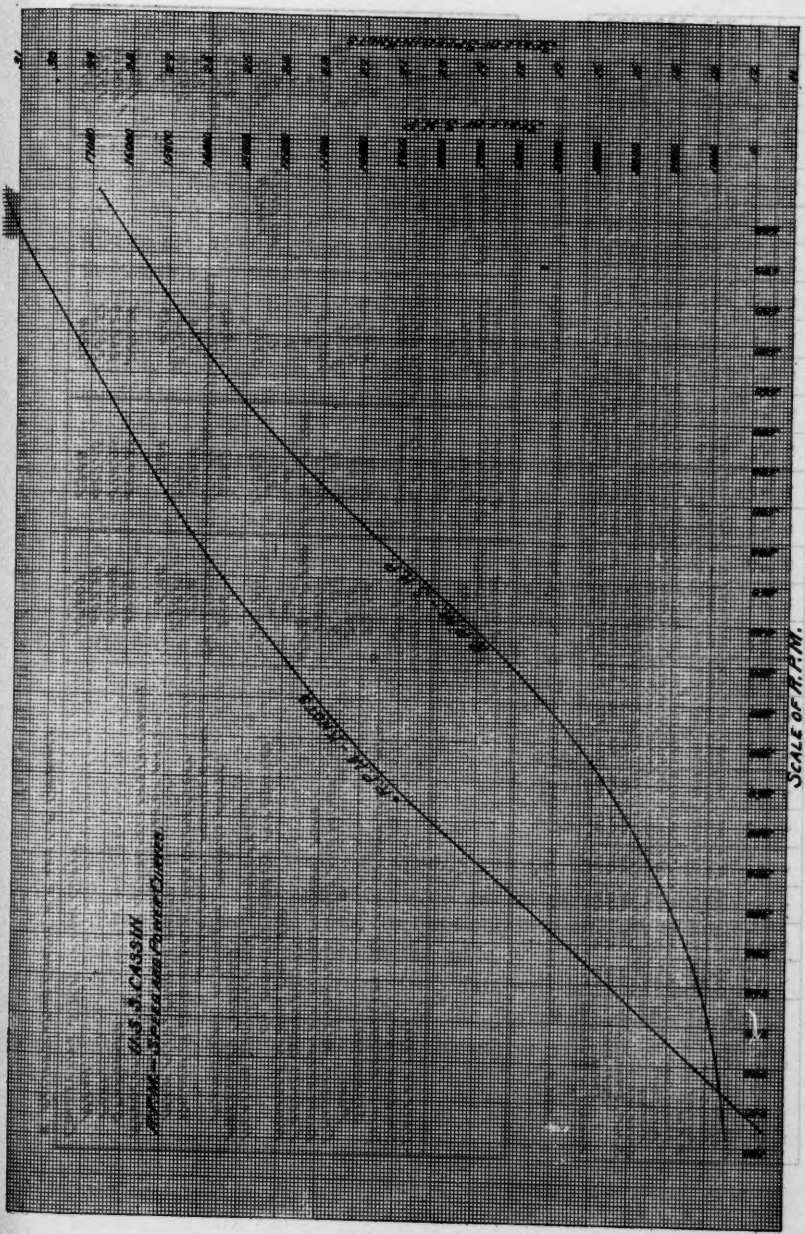


FIG. 4.

NUMBER OF RUN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
TIME ON COURSE, MINS. SECS.	5 22.2	4 54.6	5 23.3	3 49.7	4 6.4	3 53.1	3 18.8	3 12.1	3 18.6	2 46.6	2 49	2 42.5	2 30.2	2 30.2	2 30	2 18	2 17.2	2 18.1	2 5.1	2 6.6	2 4.4	1 56.9	1 53.8	1 57.1	1 52.8	1 57.6
REVOLUTIONS, TO GO 1 KT.:																										
STARBD. SHAFT	987.7	925.8	981.3	947.4	988.1	961.4	1042.1	1023.7	1037.1	1033.8	1032.0	1036.9	1064.5	1033.9	1063.9	1112.6	1094.0	1111.5	1140.7	1164.7	1135.9	1122.6	1194.6	1226.5	1176.4	1233.5
PORT SHAFT	1052.3	980.2	1055.8	1085.1	1054.4	1034.2	1006.2	984.6	1001.6	996.6	1003.2	1003.2	1031.1	1037.9	1035.4	1076.2	1069.2	1081.6	1155.5	1176.8	1158.0	1242.6	1235.2	1232.2	1229.4	1281.5
AVERAGE	1020.0	953.0	1018.3	976.3	1021.3	983.8	1024.2	1004.3	1019.5	1015.2	1017.6	1020.1	1047.8	1035.9	1049.7	1094.4	1081.6	1096.5	1148.2	1170.8	1147.0	1246.1	1214.9	1249.9	1202.9	1257.5
H.P. M.:																										
STARBD SHAFT	183.76	188.87	182.14	247.51	240.66	247.50	344.46	319.91	343.31	372.56	366.72	371.52	425.38	429.71	425.97	483.92	478.59	483.06	547.10	551.35	548.31	620.76	624.82	628.06	625.76	629.24
PORT SHAFT	195.71	199.97	195.87	262.66	257.27	259.06	303.59	307.69	302.54	359.14	356.46	359.46	412.03	415.28	414.54	468.07	462.72	463.81	554.19	557.47	558.95	650.89	651.53	652.74	653.91	653.80
AVERAGE	189.71	194.42	189.01	255.06	248.97	253.28	309.02	313.80	307.93	365.84	361.60	365.49	418.71	422.50	420.27	475.99	473.15	473.44	550.65	554.41	553.63	635.83	638.18	640.71	639.83	641.52
SPEED IN KNOTS	11.173	12.228	11.135	15.673	14.610	15.448	18.109	18.760	18.127	21.609	21.902	21.693	23.948	23.960	24.000	26.087	26.293	26.068	28.777	28.436	29.939	30.796	31.696	30.745	31.915	30.612
S.H.P., STARBD. SHAFT	184	189	189	510	498	510	1286	1280	1350	2164	2109	2274	3456	3545	3540	5217	5083	5251	6188	6224	6201	7466	7417	7625	7471	7312
PORT SHAFT	323	330	323	681	674	670	965	942	926	1523	1411	1603	2744	2641	2738	4264	4032	4224	7149	7175	6819	8891	8959	9021	9115	9192
TOTAL	507	519	512	1191	1062	1080	2251	2222	2276	3987	3720	3877	6199	6186	6338	9481	9115	9435	13337	13399	13020	16355	16376	16646	16586	16504
ENGINES IN OPERATION	RECIP. ENGINE, H.P. & L.P. TURBINES						H.P. & L.P. TURBINES (STEAM ON H.P. CRUISING BELT)															H.P. & L.P. TURBINES				

TABLE II.—STANDARDIZATION TRIAL DATA.—U. S. S. "CASSIN." COURSE OFF ROCKLAND, MAINE, JUNE 24, 1913.

	4-HOUR FULL POWER TRIAL (b)	4-HOUR 24-KNOT TRIAL (c)	4-HOUR 15½-KNOT TRIAL (d)	20-HOUR 15½-KNOT TRIAL (e)	4-HOUR 12-KNOT TRIAL (f)
DATE OF TRIAL	JUNE 26, 1913	JUNE 25, 1913	JUNE 27, 1913	JUNE 27 & 28, 1913	JUNE 25, 1913
SPEED IN KNOTS	30.137	24.048	15.522		11.999
SLIP OF PROPELLERS, PER CENT OF OWN SPEED, MEAN:					
STARBOARD	22.54	14.79	5.81		4.22
PORT	25.15	11.82	11.97		10.51
DRAUGHT, MEAN ON TRIAL, FEET AND INCHES	9 - 3¼	9 - 3½	9 - 4		9 - 3¾
DISPLACEMENT, CORRESPONDING, TONS	1011	1015.5	1022.5		1030
ENGINES IN OPERATION	H.P. & L.P. TUR.	H.P. & L.P. TUR.	*		*
NUMBER OF BOILERS USED	4	4	1		1
OIL BURNERS USED (12 PER BOILER)	46	21	6	NO DATA TAKEN	4
HEATING SURFACE USED; SQUARE FEET	21500	21500	5375		5375
PRESSURES (AVERAGE):					
MAIN STEAM, AT BOILERS, POUNDS GAUGE	256	238.2	218.63		210.2
STEAM CHEST, POUNDS GAUGE	245.2 (H.P.M. BELT)	200 (H.P.C. BELT)	197.4 (RECIP. ENG.)		94.8 (RECIP. ENG.)
VACUUM IN CONDENSER, INCHES OF MERCURY	27.8	28.4	27.6		27.6
MAIN FEED, POUNDS GAUGE	298.4	290.	279.4		293.8
AIR PRESSURE IN FIREROOMS, INCHES OF WATER	6.08	3.84	4.43		3.8
REVOLUTIONS PER MINUTE OF PROPELLERS (AVERAGE):					
STARBOARD	591.97	429.35	250.74		190.61
PORT	612.59	414.95	268.29		204.00
MEAN	602.28	422.15	259.52		197.31
COLLECTIVE S.H.P., FROM CURVE	15307	6348	1214		372

* RECIPROCATING ENGINE, H.P. AND L.P. TURBINES.

TABLE III.—U. S. S. "CASSIN."—TRIAL DATA.

average uniform speed of 15½ knots, as nearly as possible, following as closely as possible trial (d), the cruising engine connected and in use. Fuel oil and water consumption will not be determined on this trial, the purpose of which is to determine the reliability and endurance of the cruising engine.

(f) A fuel-oil and water-consumption trial of four hours' duration in the open sea, with the cruising engine connected and in use, at an average uniform speed of 12 knots, as nearly as possible.

The *Cassin's* trials were run June 24 to 28, 1913, inclusive. Excellent weather prevailed for all the trials. The standardization trial was run on the measured-mile course, at Rockland, Me., and all other trials were run in the open sea off the Maine coast.

Twenty-six runs were made on the standardization trial, at various speeds, over the measured mile, the data from which were used in plotting the curves shown in Fig. 4. The data are given in Table II.

The official speed and revolution curve gave the following mean revolutions per minute of the propellers as necessary to attain the speeds stipulated for the other trials:

Speed in knots.	R.p.m.
12	197.3
15½	259.2
24	421.1
29	565.0

The other trials were successfully run on the dates noted in Table III. The contract speed was comfortably exceeded on the full-speed trial, and the data obtained on this and the remaining trials are given in the table.

(NOTE.—The *Cummings'* trial data will be published in the November, 1913, number of the JOURNAL, as the trials will not be run until later in the year.)

THE UNDERWATER HORIZONTAL HYDRAULIC ASH DISCHARGER ON THE U. S. COLLIERS *PROTEUS* AND *NEREUS*.

By F. P. Palen, Associate.

The question of discharging ashes from the fireroom of a vessel directly into the sea has received more or less attention from marine engineers for a number of years past, and successful installations have been made for expelling ashes straight down through the bottom of the vessel. The bottom expellers, have demonstrated the desirabilty of fitting apparatus that will discharge ashes from the fireroom directly into the sea without passing through other compartments of the vessel. However, experience has shown that ashes expelled through the bottom of a vessel will find their way into the pump suctions located aft of the openings through which the ashes are expelled and cause serious wear in the pump cylinders and also block up the ends of the condenser tubes.

In order to overcome these serious objections to underwater ash expellers there has been developed at the works of the Newport News Shipbuilding and Dry Dock Company, and installed on the U. S. colliers *Proteus* and *Nereus*, a hydraulic ash discharger of the horizontal type for discharging the ashes through the side of the vessel below the water line in locations where they will drift clear of the pump suctions.

In order to illustrate the desirability of discharging the ashes through the side of the vessel there is shown on Plate I the horizontal discharger applied to a modern battleship. This drawing also shows, projected on a section of the vessel, the suction sea chests for the condenser circulating water, the auxiliary-pump suction, the propellers and strut bearings, the docking keels and the bilge keels. The locations for the

different features of the vessel are taken from actual work. It is evident from an inspection of this drawing that it is very desirable to discharge the ashes outboard of the docking and bilge keels, above the turn of the bilge, and outboard of all pump suctions and shaft strut bearings and where the stream lines will not carry them near these points. If the ashes are discharged through the bottom of the vessel and inboard of the docking keel they will be carried aft by the flow of the water and find their way into the pump suctions and propeller-shaft strut bearings.

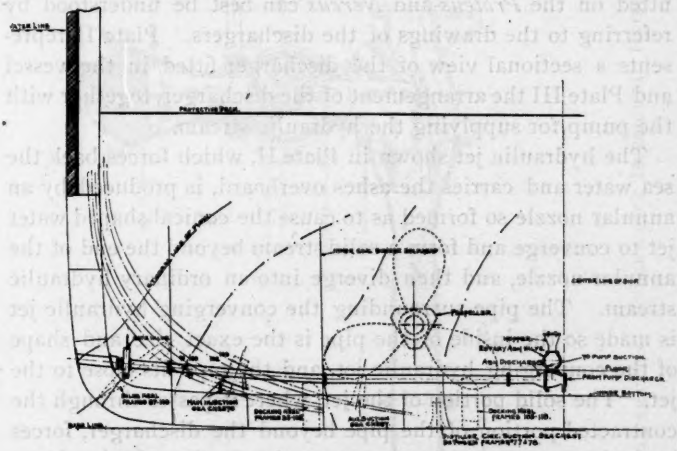


PLATE I.—SECTION OF MODERN BATTLESHIP SHOWING HYDRAULIC ASH DISCHARGER.

In order to show the path of the ashes that stay close to the ship's hull, the probable direction of the stream lines for the vessel has been indicated by dot-and-dash lines on the drawing.

This sketch also shows that it would be necessary to carry the discharge pipes through the protective deck and side armor in case ash expellers are used for discharging through the side of the vessel above the water line. The discharge pipe for the underwater discharger can, however, be led so as to discharge the ashes at any point on the side of the vessel below the water line.

Two important points should be considered in connection with discharging ashes through the ship's side and below the water line.

1st. The ashes must pass around a right-angle bend, and, therefore, some way of preventing long pieces from blocking the pipe at this point must be provided.

2d. A water jet or other means must be provided for carrying the ashes overboard and for preventing the sea water from entering the vessel.

The method of treating these questions in the dischargers fitted on the *Proteus* and *Nereus* can best be understood by referring to the drawings of the dischargers. Plate II represents a sectional view of the discharger fitted in the vessel and Plate III the arrangement of the discharger, together with the pump for supplying the hydraulic stream.

The hydraulic jet shown in Plate II, which forces back the sea water and carries the ashes overboard, is produced by an annular nozzle so formed as to cause the conical-shaped water jet to converge and form a solid stream beyond the end of the annular nozzle, and then diverge into an ordinary hydraulic stream. The pipe surrounding the converging hydraulic jet is made so the inside of the pipe is the exact size and shape of the converging hydraulic jet, and the pipe fits close to the jet. The solid portion of the jet, where it passes through the contracted portion of the pipe beyond the discharger, forces back the sea water and creates a suction in the ash pipe forming the inside ring of the annular opening through which the discharge water passes. This suction draws whatever is contained in the ash pipe into the hydraulic stream and carries it overboard.

In actual operation on the *Proteus* the jet created a suction equal to 18 inches of vacuum when the cover of the ash hopper was closed, and in the experimental machines, made for the purpose of developing the nozzle, the suction was much stronger, at times running as high as 27 inches vacuum.

The nozzle was developed by experiments on a full-sized model fitted up in an empty dock, about 22 feet below the

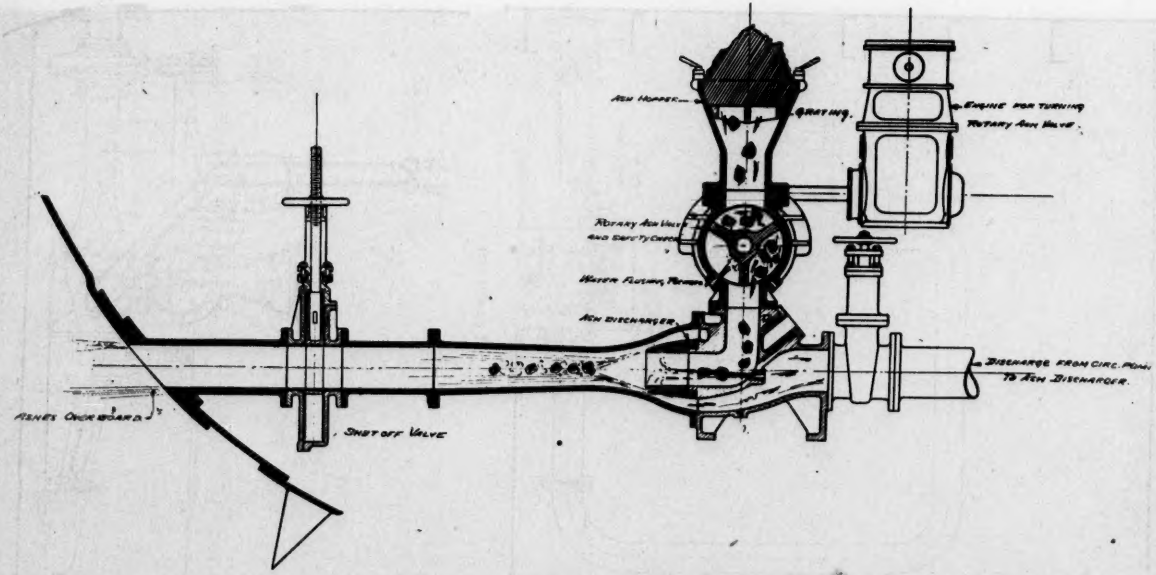
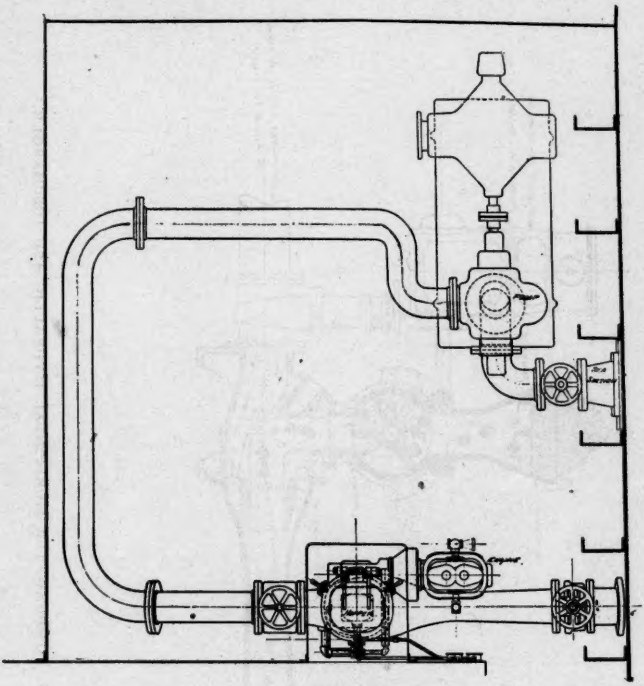


PLATE II.—SECTION SHOWING OPERATION. UNDERWATER HORIZONTAL HYDRAULIC ASH DISCHARGER.



FIREROOM.

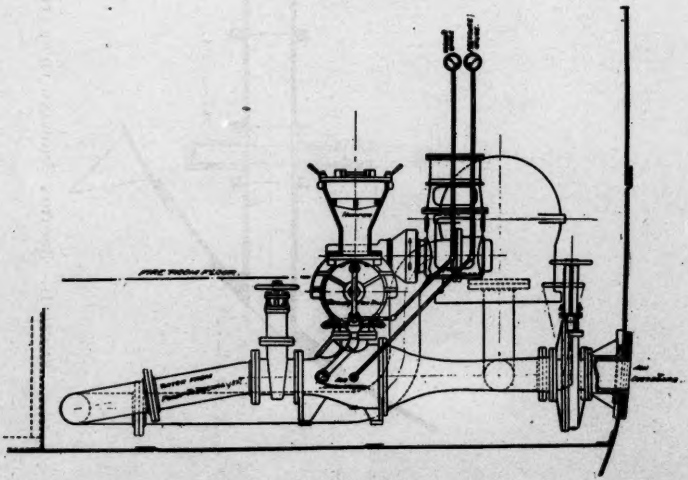


PLATE III.—ARRANGEMENT OF UNDERWATER HORIZONTAL HYDRAULIC ASH DISCHARGER.

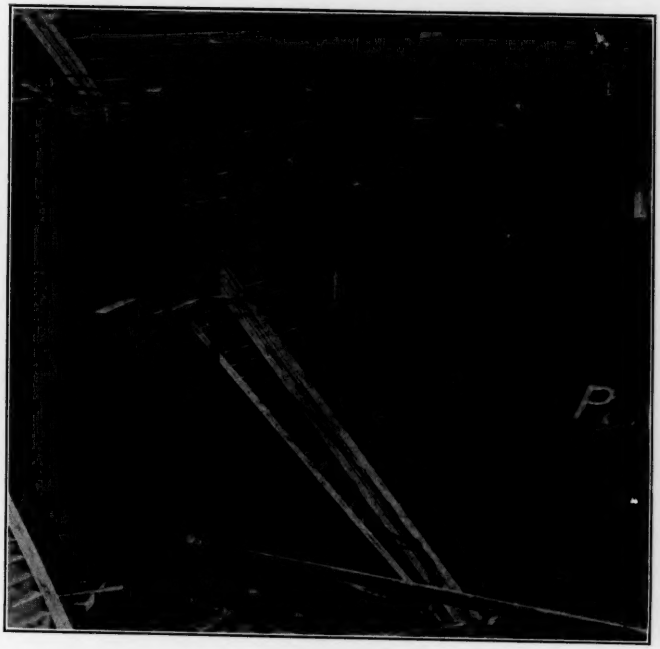


PLATE IV.

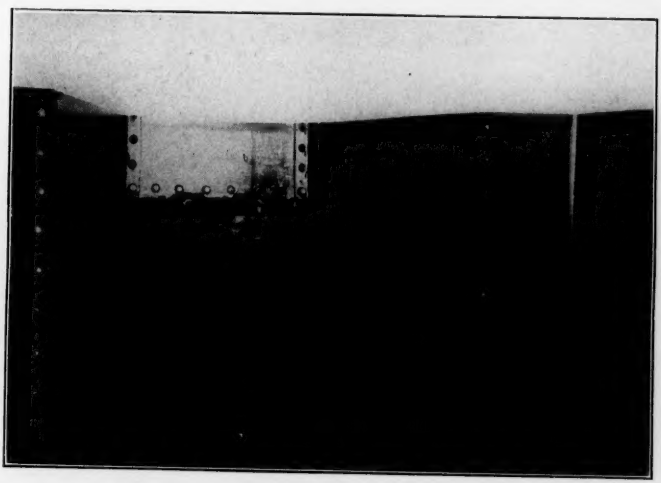


PLATE VI.

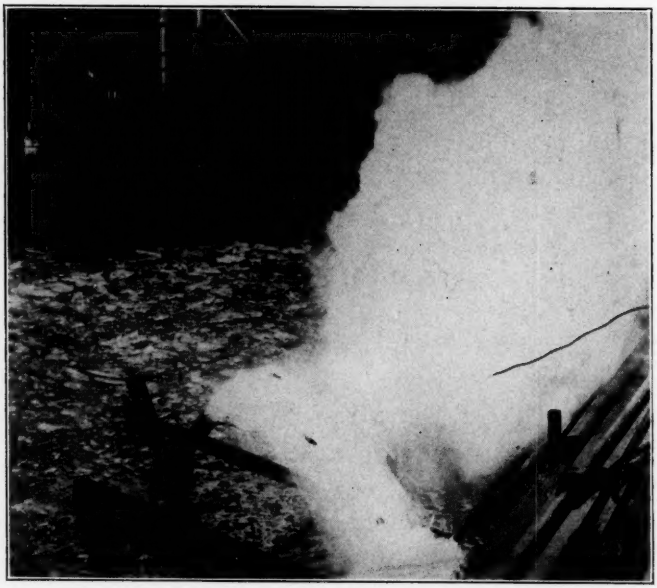


PLATE V.

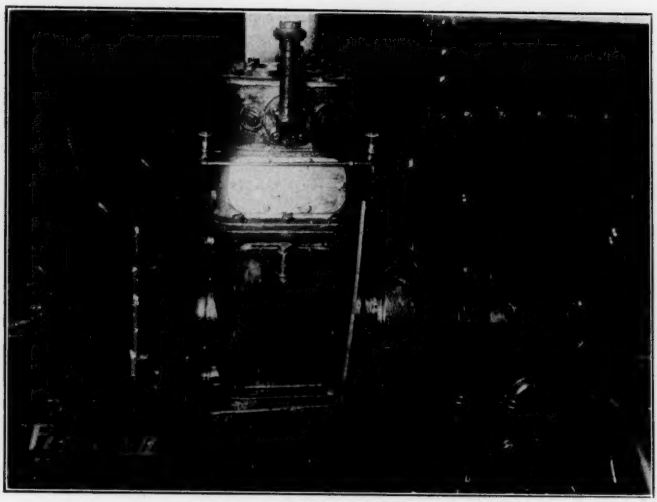


PLATE VII.

ordinary water level, and operated when the dock was flooded. Under these conditions the nozzle operated against an outside head of about 22 feet of water.

The experimental machine set up in the dry dock, with a horizontal discharge pipe 45 feet long, corresponding to a battleship installation, is shown in Plate IV. The turbine-driven centrifugal pump supplying the water for the jet is located above the water line and at the corner of the dock, and the exhaust pipe from the turbine is shown at the top of the dock with an open end. The pipe for delivering the ashes to the jet is carried up in the experimental machine so the hopper is located above the water when the dock is flooded. Plate V shows the discharger working with the discharge pipe turned up with the open end of the pipe above the water line when the dock is flooded, or about 25 feet above the discharger nozzle. At the time the picture was taken the dock was filled with floating ice. This experiment shows that the discharger will operate effectively for discharging above as well as below the water line. The open end of the exhaust pipe from the turbine causes the cloud of steam near the discharge-pipe opening.

Other special features of the design are the rotating ash valve, which is operated by a small double-cylinder engine that will start from any position. This valve is made with a hardened cast-steel rotor, and acts as a crusher and prevents pieces from passing that are too large to go around the bend in the ash pipe. The valve also serves to prevent any large inrush of water into the vessel, in case the sea valves and hopper covers are left open when the pump is not running. It is not made watertight, because the wear of the ashes makes this impracticable, but the valve will always prevent serious flooding from carelessness and will allow time to close the sea valve.

A small jet of water is introduced into the bend in the ash pipe to assist the suction to carry the ashes clear of the horizontal portion of the ash-pipe nozzle. There is no wear on the discharge pipe, as the ashes are carried out in the stream

and at a speed sufficient to shoot them clear of the side of the vessel.

The water for the hydraulic jet is supplied at comparatively low pressure from a turbine-driven centrifugal pump. The jet operates when the water pressure at the jet is equal to or slightly greater than the head of water equal to the draught of the vessel. The jet works effectively with a pressure of less than 25 pounds gage.

On the sea trials of the U. S. fleet collier *Proteus* the discharger handled ashes as fast as they could be fed through the gratings in the hoppers. This was as fast as two men could shovel the ashes into the hopper, with one man standing by to poke them when they clogged on the grating. The rated capacity of the discharger is from 12 to 15 tons per hour. For test purposes heavy clinkers and fire brick were thrown into the hopper, and the rotating ash valve crushed them readily, discharging them without difficulty. Bolts, nuts and pieces of stone are carried outboard by the discharger quite as readily as light ashes. The rotating ash valve and all parts of the engine are made heavy enough to withstand the strains produced when iron bars are thrown into the hopper, stalling the ash valve and engine. This actually happened on the sea trial of the *Proteus*, when a coal hammer was accidentally thrown into a hopper. The hammer handle was removed and the discharger started without further trouble. The discharger is noiseless when in operation.

The installation of the dischargers on the U. S. collier *Proteus* is shown in the photographs marked Plates VI and VII.

The trials on the *Proteus* have demonstrated the effectiveness of the annular jet used in this discharge, as well as the practicability of the rotating ash valve for crushing the clinkers, and at the same time protecting the vessel against flooding in case of carelessness or accident.

U. S. FLEET COLLIER *JASON*.

CONTRACT TRIALS PERFORMANCE.

By Henderson B. Gregory, Associate.

The *Jason*, Fleet Collier No. 12, was authorized by an act of Congress of March 4, 1911, and was built under contract by the Maryland Steel Company, of Sparrow's Point, Md. The contract was signed August 22, 1911, the price being $951,000.00, and the time of construction twenty-four months. She was designed for a speed of fourteen knots, at about 19,130 tons displacement, with the main engines developing about 6,800 I.H.P.

The hull and machinery are similar to the *Orion*, the sister ship, built by the same company, a description of which was published in the November, 1912, number of the Journal of the American Society of Naval Engineers, and which likewise applies to this vessel.

Principal Hull and Machinery Data.

Hull dimensions:	
Length over all, feet and inches	536–00
on L.W.L., feet and inches	514–00
Beam on L.W.L., feet and inches	65–02½
Mean designed draught, feet and inches	27–04½
Displacement corresponding, tons	19,130
Main engines:	
Number	Two (twin screw).
Type	Vertical, inverted, direct-acting, triple-expansion.
Diameter of cylinder, H.P., inches	27
I.P., inches	46
L.P., inches	76
Stroke, inches	48
R.p.m. (design)	90
I.H.P. (design)	6,800

Main boilers:

Number	3
Type	Double-ended, Scotch.
Working pressure, pounds	200
Diameter, external, feet and inches	16–01 9/16
Length, external, feet and inches	21–04 3/4
Number of furnaces each	8
Grate surface, square feet	146.7
Heating surface, square feet	6,307
Ratio G.S. to H.S.	1 to 43

The vessel was constructed in comformity with the Rules of the American Bureau of Shipping and the Rules of the United States Steamboat Inspection Service. Inspection was carried out during the construction of the vessel by the representatives of both organizations, and the inspection certificates of both were furnished the Navy Department upon completion of the vessel.

TRIALS.

The contract required:

(*a*) A progressive trial of about 17 runs over the measured-mile course at Delaware Breakwater for the purpose of standardization of the screws, with the vessel in full-load condition.

(*b*) A full-speed trial of 48* hours duration, in the open sea, in deep water, at an average speed of not less than 14 knots. On this trial it was required that the air pressure in the ash pits should not exceed 1¼ inches of water, and the steam pressure at the H.P. valve chest should not exceed 195 pounds per square inch above the atmosphere.

(*c*) Complete trials of the coaling appliances and apparatus of the vessel. Also similar trials of the oil-fuel handling appliances.

Standardization Trial.—On June 18, 1913, the standardization trial was run on the mile course off Delaware Breakwater. Sixteen runs were made over the course at various speeds, as shown in Table I, which gives the principal data. Runs Nos. 12 and 13 were thrown out and not used in com-

*Subsequently changed to 24 hours.

TABLE I.- STANDARDIZATION TRIAL DATA U.S. COLLIER "JASON".

COURSE OFF DELAWARE BREAKWATER, JUNE 18, 1913.

NUMBER OF RUN.....	1	2	3	4	5	6	7	8	9	10	11	14	15	16
TIME ON COURSE, MINS.. SECS..	4 50.9	4 20	5 14.1	3 39.2	4 49	3 42.3	4 37.1	3 49.8	5 44.4	5 2.9	5 17.7	10 21.5	6 10.1	9 24
REVOLUTIONS TO GO 1-MI:														
STARBD. ENGINE....	411.7	372.1	447.3	354.0	462.8	361.7	440.5	374.1	411.8	358.8	392.0	525.0	328.5	503.2
PORT ENGINE.....	411.0	366.8	444.0	347.0	457.1	352.6	436.5	369.9	411.3	356.2	396.8	505.5	353.6	485.8
AVERAGE.....	411.35	369.45	445.65	350.5	459.95	357.15	438.5	372.0	411.55	357.5	394.4	515.25	341.05	494.5
R.P.M.:														
STARBD. ENGINE....	85.01	85.94	85.45	96.93	96.10	97.60	95.38	97.64	71.71	70.98	74.03	50.68	53.26	53.52
PORT ENGINE.....	84.86	84.71	84.80	95.01	94.91	95.16	94.50	96.54	71.62	70.46	74.93	48.79	57.35	51.67
AVERAGE.....	84.94	85.33	85.13	95.97	95.51	96.38	94.94	97.09	71.67	70.72	74.48	49.74	55.31	52.60
SPEED IN KNOTS.....	12.375	13.846	11.461	16.423	12.457	16.194	12.992	15.666	10.453	11.885	11.331	5.792	9.727	6.283
I.H.P., STARBD. ENG..	2481	2452	2519	3050	3642	3832	3465	3462	1432	1421	1573	482	729	590
PORT ENG.....	2332	2323	2362	3390	3763	3628	3777	3742	1289	1268	1912	580	816	578
TOTAL.....	4813	4775	4881	6440	7405	7460	7242	7204	2721	2689	3485	1062	1545	1168

puting the data. The estimated displacement at the middle of the high-speed runs was 18,922 tons, and corresponding mean draught 27 feet 3 inches. The curves, Figure 1, were plotted from the data given in Table I. From the official curves it was found to require 93.1 revolutions per minute of the main engines to give the contract speed of 14 knots.

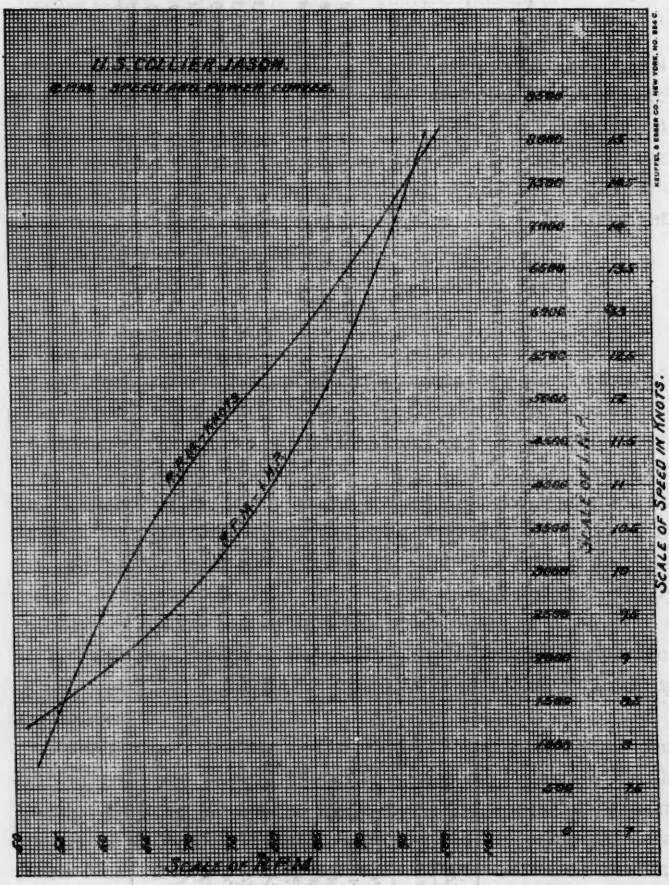


FIG. 1.

Twenty-Four Hours Full-Speed Trial.—This trial was held in the open sea on June 18th and 19th, 1913. The weather during the trial was exceptionally fine with a smooth sea and little or no breeze.

The trial was entirely satisfactory and the contract speed of 14 knots was easily exceeded.

The averages of the data taken on the trial are given in Table II. It was estimated that the mean displacement at the middle of the trial was 18,862 tons, and corresponding mean draught 27 feet and ½ inch.

TABLE II.—DATA OF TWENTY-FOUR HOURS FULL-POWER TRIAL, U. S. COLLIER "JASON" OFF ATLANTIC COAST, JUNE 18 AND 19, 1913.

Average revolutions per minute, starboard engine	96.04
port engine	94.35
both engines	95.20
steam pressure at boilers, pounds gage	199.6
engines, pounds gage	194.9
air pressure in ash pits, inches of water	1.334
vacuum, starboard condenser, inches of mercury	25.84
port condenser, inches of mercury	26.14
I.H.P., starboard engine	3,377
port engine	3,501
total	6,878
Mean draught during trial, feet and inches	27–00½
Corresponding displacement, tons	18,862
Mean speed, in knots	14.322
Slip of propeller, in per cent. of own speed, starboard	16.05
port	14.55

TEST OF COALING GEAR.

On March 17, 1913, the coaling gear of one hatch was tested for capacity of unloading. The collier *Mars* was secured alongside the *Jason*, and lines were erected on the *Mars* to mark 27 feet above the *Jason's* deck and 54 feet 6 inches outboard of the center of the hatch, to enable the Board to estimate the height and the distance outboard of the hatch to which the coal was hoisted before it was dumped. The test was conducted for one hour, at the end of which time 128 tons of coal had been dumped, which was well in excess of the con-

tractor's guarantee of 100 tons per hatch per hour, and the trial was, therefore, discontinued. The gear and its operation were satisfactory.

After this test each hatch athwartship gear was operated for a brief period to ascertain if they functioned properly, and all were found to be in good working order and performed the work required satisfactorily. There are eleven hatches in all.

On June 5, 1913, while alongside the dock of the Maryland Steel Company at Sparrow's Point, Md., a fifteen-minute test of the fore-and-aft coal-transfer gear was conducted as follows:

A 1⅛-cubic-yard bucket was loaded with coal, total weight of coal and bucket being about 6,600 pounds. The loaded bucket was then raised from the after hatch, trolleyed to the forward hatch and lowered just inside the hatch, hoisted again, trolleyed aft and lowered to the level of the after hatch. Eight complete round trips as above were made in fourteen and one-half minutes, which was at the rate of about seventy-two tons of coal an hour.

During the trials the gear was operated by a skilled man, and, in order to derive the most benefit from the gear, it will be necessary that intelligent men be trained in its operation.

TESTS OF FUEL-OIL HANDLING GEAR.

The tests of the fuel-oil handling gear were conducted on February 19, 1913.

The capacity of the fuel-oil pump to take water from the four fuel-oil holds forward and double bottoms, compartments Nos. 5 and 6, which are fitted for carrying fuel oil, was tested. As no oil was available, salt water was used, and the pump discharged same overboard through the four standpipes on the main deck.

The test was conducted for one hour, in which time 138,150 gallons of water were discharged, the guarantee being only 125,600 gallons. The pump worked smoothly during the test, the result of which was considered most satisfactory.

THE SAVING OF HEAT UNITS IN MARINE MACHINERY.

By Lieutenant Commander Henry C. Dinger, U. S. N., Member.

Economy is a very important matter in the operation of commercial, marine and naval machinery, and a matter that is now receiving considerable more consideration than it did some years ago. It may be a matter of interest, and serve as a suggestion for practical improvement, to discuss the possible results of several methods of securing economy which are entirely adaptable to marine work. In the present installations, and also in those under construction, many heat units are being pumped overboard which, by the installation of a few entirely practical and simple devices, could be saved.

Granted that the greatest economy at the various speeds on the least total weight is desirable, we may ask what kind of a steam plant will best give us these results for large naval vessels.

We have the following systems to choose from:

(*a*) Improved reciprocating engine, fitted with forced lubrication and using superheated steam.

(*b*) Turbines, direct, employing latest developments.

(*c*) Electric drive, steam turbines and electric motors, using either superheat or without it.

(*d*) Combination or reciprocating engine and L.P. turbine.

The reciprocating engine fitted with forced lubrication and superheated steam is a type represented by the engines of the *Delaware*, *New York*, etc. The best results at full speed secure us an economy of about 13.5 pounds of water per I.H.P., while at the most economical point (at two-thirds power), about 12.5 pounds of water per I.H.P. This engine

is reliable; the high-pressure end is very efficient. It can use superheated steam efficiently, but the low-pressure end cannot properly use a low vacuum. At high powers, 30,000 H.P. and above, for twin screws the low-pressure cylinders are unusually large and become unwieldy.

An examination of the steam-expansion curve, Fig. 1, with a line drawn at 5 pounds absolute back pressure and another at 1 pound absolute (part cross-hatched) gives us the area of work that the low-pressure end of the reciprocating engine rejects and which the low-pressure end of the turbine utilizes. In practice, the turbine uses some of the area below the 1-pound line. The reciprocating engine gets more out of the steam from boiler pressure down to atmosphere; but the turbine gets far more out of the steam from atmospheric pressure down.

By using each type of engine for the part of the operation to which it is best suited an overwhelming advantage in economy can be secured. From data based on the trials of the *Delaware* and *Michigan* and the trials of the *Utah* and *Florida* the following results, as far as water consumption is concerned, may be expected.

A reciprocating engine using steam at 275 pounds absolute, superheated 90 degrees F. and expanding down to about 17 pounds absolute, will develop .062 horsepower per pound of water used. A low-pressure Parsons turbine using this exhaust can develop .042 horsepower per pound of water used. Or the two together will develop .104 horsepower per pound of water, or will require 9.61 pounds of water per horsepower. About the same result can be secured with a L.P. turbine of Curtis or other type in place of Parsons.

The French liner *Rochambeau*, an actual installation, employing a quadruple-expansion engine and L.P. Parsons turbine, without superheat, and an intitial pressure of only 230 pounds absolute, developed .092 horsepower per pound of water, or 10.9 pounds water per horsepower.

These are the results from actual engines, and, moreover, from engines that can be improved upon in design and

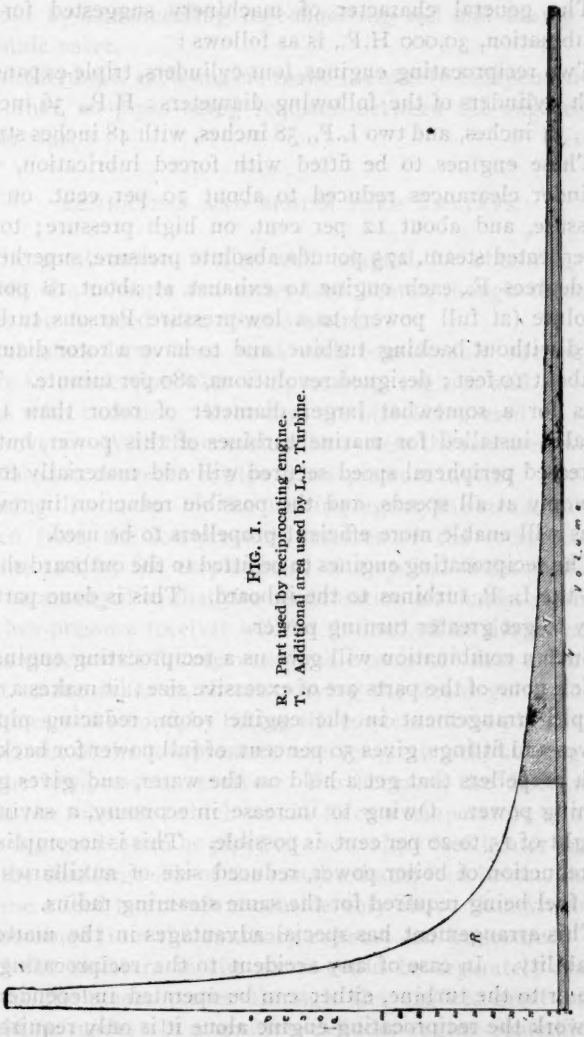


FIG. 1.

construction. The best performance that the marine turbine alone can show is about 11.5 pounds of water per S.H.P. This is on some of the latest English battle cruisers.

The general character of machinery suggested for the combination, 30,000 H.P., is as follows:

Two reciprocating engines, four cylinders, triple-expansion, with cylinders of the following diameters: H.P., 36 inches; I.P., 54 inches, and two L.P., 58 inches, with 48 inches stroke.

These engines to be fitted with forced lubrication, with cylinder clearances reduced to about 10 per cent. on low pressure, and about 12 per cent. on high pressure; to use superheated steam, 275 pounds absolute pressure, superheated 90 degrees F., each engine to exhaust at about 18 pounds absolute (at full power) to a low-pressure Parsons turbine, fitted without backing turbine, and to have a rotor diameter of about 10 feet; designed revolutions, 280 per minute. This calls for a somewhat larger diameter of rotor than those usually installed for marine turbines of this power, but the increased peripheral speed secured will add materially to the economy at all speeds, and the possible reduction in revolutions will enable more efficient propellers to be used.

The reciprocating engines to be fitted to the outboard shafts, and the L. P. turbines to the inboard. This is done particularly to get greater turning power.

Such a combination will give us a reciprocating engine in which none of the parts are of excessive size; it makes a very simple arrangement in the engine room, reducing piping, valves and fittings, gives 50 per cent. of full power for backing, with propellers that get a hold on the water, and gives great turning power. Owing to increase in economy, a saving of weight of 15 to 20 per cent. is possible. This is accomplished by reduction of boiler power, reduced size of auxiliaries and less fuel being required for the same steaming radius.

This arrangement has special advantages in the matter of reliability. In case of any accident to the reciprocating engine or to the turbine, either can be operated independently. To work the reciprocating engine alone it is only required to shift the differential valve so that the exhaust enters the condenser. Any cylinder of the reciprocating engine could be

cut out by disconnecting its connecting rod and taking out the slide valve.

Furthermore, each engine room is entirely independent of the other, no pipes being required between the engines on either side.

REHEATERS AND SERIES FEED HEATERS.

The combination is also well adapted for obtaining the benefit of a reheater and series feed heater, though these devices can be used with other systems.

Reheaters have been used with considerable success on shore in connection with reciprocating engines and in some cases with turbines. Reheaters are also being used on some destroyers. With the combination system the reheaters would be placed in the receiver pipe to low-pressure turbine. Instead of using live steam for the heating agent, the steam can be taken from the low-pressure receiver of the reciprocating engine and, by the employment of a special drain pocket, it can be arranged so that the condensation and moist steam in the low-pressure receiver will be drained off to the reheaters. This system will thus serve a double purpose: first to furnish heat to the reheater, thereby drying the steam going to the turbines, and second, by taking the condensation and entrained water out of the low-pressure receiver, drying the steam going to the low-pressure receiver. Furthermore, the drain water from the reheater (which would have a temperature of about 280 degrees F.) can be piped to a secondary feed heater located on the discharge side of the usual exhaust-feed heater, and by its use a feed temperature considerably above that which can be obtained from the auxiliary exhaust can be secured.

If the moisture in the steam could be separately drained off as the steam passes through the engine, great saving could be made. In a multiple-cylinder engine something of this nature may be possible by taking some of the condensation out at the receivers.

Suppose it is possible to drain off this condensation each time, the results may be examined as follows:

Take steam at 260 pounds, in a triple-expansion engine, pressure, I.P., 110 pounds; L.P., 25 pounds.

Total heat 1 pound of dry steam at 260 pounds=1,205 B.t.u.

If expanded down to 1.5 pounds absolute adiabatic expansion, the heat units=874, steam 78 per cent. dry. Heat extracted, 1,205—874=330 B.t.u.

Let this represent the available heat in the ordinary engine.

Where moisture is drained off:

Starting with steam at 260 pounds, total heat 1,205 B.t.u.

Expanding to 110 pounds, total heat 1,130, steam 93 per cent. dry.

Dry at 110, expanding to 25 pounds, total heat 1,075, steam 90 per cent. dry.

Dry at 25, expanding to 1.5 pounds, total heat 976, steam 87 per cent. dry.

	B.t.u.
Heat used in H.P. cylinder, 1,205—1,130 = ...	75.00
Heat used in I.P. cylinder, (1130—1075) × .93 = .	51.15
Heat used in L.P. cylinder, (1075—976) × .83 = .	83.00
Heat in .093 pound of steam at 25 pounds above 200 degrees F., steam drained from L.P. receiver = .	91.8
Heat in .07 pound of steam at 110 pounds above 200 degrees F., steam drained from I.P. receiver = .	70.1
Total heat obtained when all moisture is drained off,	371.05
Total available heat ordinarily, ...	330.00
Difference, ...	41.05

Or, taking it another way, in second case only:

976×(.92×.90)+(.163×168) = . . . 842 } is rejected
Heat rejected ordinarily = ... 874 } to cylinders.
168 is heat in water at 200 degrees F.

Difference, ... 32 B.t.u. saved.

By both methods a decided saving of heat is shown to be possible, and hence there is shown that in the development of methods of getting rid of moisture at the various receivers, a means for improving economy of steam consumption may be secured.

This analysis indicates that a saving of about 10 per cent. would be possible if all moisture were extracted from the steam in each receiver. There is now no certain way of doing this except, perhaps, to drain off all possible condensation and to reheat the steam each time. The heat used by the reheater will, of course, call for an extra supply of heat. By the method of drainage proposed some of the condensation will be taken out of the low-pressure receiver by draining, and the heat contained in the steam and water drained off will be used to dry the steam going to the turbine.

As it is intended that superheated steam will be used, the steam entering the I.P. cylinder at about 120 pounds pressure will be practically dry. Actual experiment on triple-expansion engines using 80 degrees superheat and 275 pounds pressure show that it is just about dry. On reaching the L.P. receiver, about 50 pounds absolute, the steam will have about 7 per cent. moisture. Some of this moisture can be drained off. The steam on reaching the turbine, if not reheated, would have about 11 per cent. moisture. If some of the moisture is drained off in the L.P. receiver this moisture might be reduced to about 8 or 9 per cent., and by means of the reheaters this steam may be dried still more. It will require about 8 per cent., of the total steam passing through to bring the steam entering the turbine to a dry condition. Whether it would actually be advantageous to use as large a quantity of steam as this for reheating is a matter to be determined by experiment. From actual practice it is known that economy does result by the use of the reheaters. Data on this subject is, however, quite scarce, and definite knowledge on the subject of reheaters somewhat vague.

A general idea of the manner of handling the steam with

the devices purposed may be obtained from the accompanying diagram, Fig. 2.

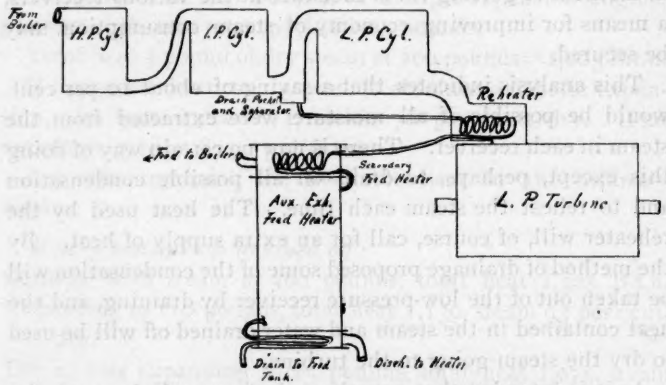


FIG. 2.—DIAGRAM SHOWING POSITION OF REHEATER AND SECONDARY FEED HEATER.

Steam in superheated condition enters the H.P. cylinder. It leaves this cylinder as saturated steam at about 110 pounds. It then passes through the I.P. cylinder and leaves that cylinder with about 7 per cent. moisture. At this point, by means of a separating and draining device, about 7 per cent. of the steam and entrained water is drained off and goes to the reheater, located in the receivers of the L.P. turbine. The steam having got rid of some of its moisture by the separating device, then goes to the L.P. cylinder, leaving this cylinder containing 8 to 10 per cent. moisture. It then passes through the reheater and is dried by means of the moist steam drained from the L.P. receiver and then enters the turbine and is condensed in the condenser.

The moist steam drained from the L.P. receiver, which has a temperature of about 240 degrees F., in passing through the reheater gives up some of its latent heat to the steam going to the L.P. turbine, but the temperature of the moisture remains at 240 degrees F. This, on leaving the reheater, goes

to the secondary feed heater, and here is all converted into water by heating the feed above the temperature of 200 degrees, at which temperature it issues from the auxiliary exhaust-feed heater. The water, leaving the secondary feed-heater coil at 240 degrees, or slightly below this, then is led into the steam space of the auxiliary exhaust-feed heater, and the latent heat and the sensible heat above 200 degrees is here extracted in heating the feed water. The water condensed from the auxiliary exhaust and from the steam taken through reheater is finally drained to feed tank, arriving there at a temperature of about 200 degrees.

By this process about 3 to 6 per cent. less heat is rejected to the condenser, and the actual gain in economy may be as high as 8 per cent., or even more, depending on the degree of saving the process of reheating will produce. A 4 per cent. gain in economy is almost certain.

It is unquestionably true that some reheating would result in an economical advantage. It seems that a practical attempt would use about 5 per cent. of the total steam, and then vary this to 10 per cent., and note results. As all the latent heat of the steam sent to the heater will be utilized in the feed heater, there is bound to be a material gain in economy, since less heat is rejected to the condenser.

The theoretical possibilities of saving by using, say, 7 per cent. of the total steam in reheater may also be analyzed as follows:

Steam at 260 pounds, superheated 75 degrees F., will contain 1,250 B.t.u.

Adiabatic expansion to 1 pound absolute gives 890 B.t.u.

Heat available, 370 B.t.u.

If reheater is used as proposed:

Steam expanding from 260 pounds, 75 degrees F. superheated, adiabatic expansion to low-pressure receiver at a pressure of 50 pounds absolute will contain, ... 1,120, B.t.u.

	B.t.u.
Heat used in H.P. and I.P. cylinder, 1,250 — 1,120 =	130.00
Now drain off 7 per cent. of steam to reheater and expand to 15 pounds absolute.	
Heat used in L.P. cylinder = (1,120 × .93) — (1,045 × .093) = ...	69.7
The steam drained off has 1,120 × .7 = 78.4 B.t.u.	
The steam on leaving L.P. will be .89 dry.	
If this steam is used in the turbine, heat used will be equal to (1,045 × .93 — 890 × .93), which equals	144.0
Total, ...	343.7

The heat contained in steam drained off from L.P. is 78.4 B.t.u. There is 64.0 B.t.u. of this available for reheating and for the heating of feed water above 200 degrees F. Just what gain will actually be brought about by the reheating cannot as yet be calculated.

Heat available for reheating and feed heating, . .	64.0
Total, ...	407.7
Result from ordinary use, ...	370.0
Saved from condenser, ...	37.7

Whether more saving could be accomplished by the reheater than by the secondary feed heater is a matter that should be determined by experiment. With this heat available the feed could be raised 64 degrees F. Theoretically, working from steam curves, the reheating does not save anything. But in practice reheaters do save. At any rate, there is no question that the heat used in the secondary heater would be a saving.

The cylinders of a marine reciprocating engine have an efficiency of about 75 per cent. This loss in efficiency has not all been definitely accounted for. Some of it is due to clearances, some to condensation and re-evaporation, some to leakage, some to friction. The losses due to clearance and those due to friction have by present improvement in design been greatly reduced. The losses due to initial condensation

are reduced by the use of superheat, and the losses due to re-evaporation and condensation in the intermediate and low-pressure cylinders can, it is believed, be reduced by the use of receiver drains and reheaters.

The low-pressure turbine of Parsons design has an efficiency of about 70 per cent. at designed power. It is believed that by the use of reheaters this efficiency can be increased by several per cent. Actual data on this matter to show the effects of different amounts of reheating would be of great interest, and such data will no doubt soon be available when some of the turbine installations, using reheaters, are tried out.

By the combination of reheaters and series feed heaters a reduction in the average fuel consumption of from 5 to 10 per cent. can be made, and at a cost and added weight that, considering total weight and cost of plant, is almost negligible.

All systems for improving economy which are not entirely simple appear to have a hard fight in marine naval engineering practice. Feed heaters had a hard time of it. A few years ago in installations where they were fitted they would often be found disconnected. Double-effect evaporators were taken up and then abandoned, and then taken up again. Now they are operated with more ease than the single-effect used to be. Evaporator feed heaters had to fight their way before they were actually recognized and used. Reheaters and secondary-series feed heaters will, no doubt, have to travel along the same path. There can be no question that their use will increase economy. Just how much, of course, can not be told until after they have been tried. The cost of trying them out, however, is very small, while the saving made possible may be a very substantial one.

POSSIBLE ECONOMY OF COMBINATION BASED ON ACTUAL WATER CONSUMPTION.

The economy to be obtained from the combination of reciprocating engines and L.P. turbines can be very closely calculated from the actual water consumption of our late battleships. The water consumption data of the *Delaware* and of the four

Parsons turbine battleships is at hand, and from this data the water consumption of the combination can be definitely found for an installation in which the reciprocating engines give the same efficiency as the H.P. and the I.P. cylinders of the *Delaware*, and the turbine the same efficiency as that of the L.P. turbine of the *Florida* or *Wyoming*.

At full power a L.P. turbine of Parsons design will secure from 70 to 75 per cent. efficiency (actual performance). The H.P. turbine will secure from 60 to 65 per cent. efficiency (result of actual performance).

The *Delaware* engines for H.P. and L.P. cylinders give an efficiency of 77 per cent. (actual results, water measured). On this basis, the combined efficiency of the combination of a triple-expansion engine and L.P. turbine should be about 75 per cent. This under the conditions: initial pressure, 260 absolute; superheat, 75 degrees F., and a vacuum of ½ pound absolute, will give a water consumption of 8.7 water per H.P.

The combination on the *Rochambeau* shows an efficiency of 70 per cent., about what is to be expected from the design used in this vessel.

From the above, all based on absolute data of actual performance, a water consumption of 9 pounds of water per horsepower at full power can be realized instead of 11.5, the best practical result now secured with turbines; and 12.3, the best realized with a straight reciprocating engine with all present improvements.

It is interesting to note that the high-speed Curtis turbine, to be used with the electric drive on the collier *Jupiter*, has shown an efficiency of 72 per cent. and that the electric transmission has 92 per cent. efficiency, or an over-all efficiency of 66.2 per cent. for the installation. This, under same conditions of steam and vacuum as given above for the combination, will give the result of 10.2 pounds of water per H.P. This is not within 10 per cent. of what the combination can give, but is about 10 per cent. more economical than the all-turbine proposition and about 25 per cent. better than the all-reciprocating engine. The above performances of electric

drive are from a shop test, and not an actual test with the vessel in service.

It may be news to some marine engineers, but it is not unusual, to secure 80 to 85 per cent. efficiency in large reciprocating engines ashore. Eighty per cent. has been guaranteed by makers for many years. Now it is maintained that 80 per cent. efficiency can be secured in a marine engine, working down to atmosphere, of the type suitable for installation in combination with the turbine. Such a high efficiency has not been secured with the H.P. end of any turbine. The principal methods of securing economy in the reciprocating engine are (1) reduction of clearances; (2) properly proportioned cylinders and valve passages, and (3) the design of receiver piping that will avoid obstructions to the steam flow. It is confidently expected that the H.P. and I.P. cylinders of the *New York* and *Texas* will show at least 80 per cent. efficiency. If 80 per cent. efficiency can be secured for the reciprocating engine, and if some improvement can also be made in the L.P. turbine (entirely possible if slightly larger diameters are permitted), an efficiency of 78 per cent. at full power for the combination may be expected, and a water rate of 8.3 pounds per H.P. is a practical possibility. It is done simply by using two economical machines together instead of hitching each up with a wasteful mate.

By the use of reheaters and series feed heaters these results will be bettered still further, so that an efficiency of 80 per cent. for the whole range and a water consumption of about 8 pounds of water per horsepower for a large marine installation is within the limits of possibility. This is not much greater improvement than what the engines of the *Michigan* accomplished over those of the *Connecticut* class. This increase in economy is available and can be secured if we go after it.

There is nothing wonderful or novel about the proposition and nothing specially new. The parts of the apparatus are not experimental, but all are fully tried. The combination has been tried for four years in the White Star Liners.

STRAIGHT TURBINES AS COMPARED WITH THE COMBINATION.

During the past few years there has been a reaction from the use of turbines for battleship propulsion, and as a result numerous battleships are being built with reciprocating engines as their motive power. The principal reason assigned to this change of thought has been the lack of economy of the turbines at low speeds. The advantages of the turbines are principally:

(*a*) Greater ease and flexibility of operation, enabling high speeds to be steadily maintained;

(*b*) Absence of vibration;

(*c*) When properly built and installed, less maintenance expenses;

(*d*) Due to non-use of internal lubrication, boilers can be kept continually clean, there being no oil deposit;

(*e*) Greater economy at high speeds than can be secured with reciprocating engines.

The disadvantages are:

(*a*) Deficient maneuvering and backing powers;

(*b*) Danger of blade troubles in the high-pressure and cruising elements.

The advantages of the reciprocating engines are:

(*a*) Better economy at low speeds;

(*b*) Better ability to repair accidents by own force.

The disadvantages are:

(*a*) Difficulty of maintaining high continuous speed;

(*b*) Inability to properly use a high vacuum, and consequent large decrease in economy at full power.

For high-speed running the turbine has the advantage. For low speeds and maneuvering the reciprocating engine has the advantage.

In the combination system superior maneuvering qualities are secured. The full advantage of a high vacuum is utilized. Superior economy is secured for both high and low speeds. Danger of blading troubles is eliminated, as only a L.P. turbine is used. Greater simplicity is secured than with the four-shaft

turbine arrangement employing cruising turbines. Less floor space is needed than for the turbine installation.

From the above it will be seen that a step from the turbines to the combination would have secured economy while retaining all the essential advantages that the turbines possess. But in changing from the turbine to the reciprocating engine the advantages of the turbine were lost and the only gain was a slight increase in steaming radius at low speeds.

If a naval vessel is expected to cruise at relatively high speeds it would appear advisable to use turbines. If economy at low speeds is deemed to be essential, the combination should be employed. For large merchant vessels the combination has an unquestionable advantage by reason of its superior economy; and this advantage is being used on many new vessels abroad.

The electric drive is a possibility to be judged after actual results in a vessel have demonstrated what it can actually do and what practical limitations and modifications may be necessary. Shop tests indicate that the electric drive will secure an advantage in economy over present turbine practice, but it will still be considerably less economical than the combination system.

RELATIVE FUEL CONSUMPTION AT LOW POWERS. TURBINES, RECIPROCATING ENGINES, COMBINATIONS.

The difference in coal consumption for a late turbine and a reciprocating-engined battleship of same date at a speed of 12 knots is about 10 per cent. The following from official trials may be quoted:

Delaware, speed, 12.24; I.H.P., 4,246; coal per hour, 10,438 pounds.

Utah, speed, 12.018; I.H.P., 4,481; coal per hour, 11,085 pounds.

There is here a difference of 12 per cent. for equal speeds. Under actual conditions of service the difference is about the same as above, and on some days, at 10 and 12 knots, the

Parsons turbined vessel has actually used less coal than the reciprocating-engined ship. The knots per ton of the *Delaware* for the year 1911–1912 at 11 knots was only 4.5 per cent. greater than that of the *Utah* for the year 1912–1913.

The steaming radius at 10 knots will not be increased more than 12 per cent. by the use of reciprocating engines, instead of turbines of late design. By the adoption of the combination system it can be increased by about 20 per cent. above that with the turbines, and at least 10 per cent. above that with the reciprocating engine.

From the data at hand we may also ascertain the economy of the combination at low speeds. Taking the results of the *Delaware* and *Florida* at 12 knots, official trials, water-consumption data.

The efficiency of the *Delaware's* engines on 12-knot trial working from 252 pounds and 50 degrees superheat to a vacuum of 27 inches works out to be 50 per cent.

The efficiency of the H.P. and the I.P. cylinders of the *Delaware* at 12 knots also works out to be 50 per cent.

The L.P. turbines of the *Florida* from the data of her official trial at 12 knots give an efficiency of about 50 per cent.

The efficiency of the cylinders of a reciprocating engine at about 15 per cent. of full power is about 50 per cent. In the combination at this speed the power will be divided on the shafts about in the proportion of one is to two; that is, the reciprocating engine will develop about twice the power that the L.P. turbine does. The engine taking the steam at about 200 pounds, superheated 100 degrees F., will exhaust into the turbine at about 6 pounds absolute. Under these conditions the reciprocating engine will (on the basis of 50 per cent. efficiency) give a water consumption of 20 pounds of water per I.H.P. The turbine using this exhaust will give a water consumption of about 40 pounds of water per S.H.P. Combining these two on the basis that the power of the reciprocating engine is twice that of the turbine (the approximate condition at 12 knots) gives a water consumption for the combination of 13.3 pounds of water per H.P.

This does not take into account the power derived from the auxiliary exhaust, which is much larger when used in a L.P. turbine than when put into the L.P. cylinder of the reciprocating engine.

The water consumption of the *Delaware* on her 12-knot trial was 15.12. The combination would therefore show a gain of about 12 per cent. in economy above the *Delaware's* performance at 12 knots.

The efficiency of the *Florida's* turbines, utilizing cruising units, at 12 knots, is 46.4 per cent., or 7 per cent. less than the reciprocating engine of the *Delaware* and about 21 per cent. less than the combination would give.

This is from actual results. No theory about it. Water-consumption tests on the cruising combination in destroyer units have corroborated the expectations of these high efficiencies.

With the combination the *Delaware* and the *Florida* could secure a water consumption for main engines at 12 knots of between 12.5 and 13.5 pounds of water per S.H.P., and, counting the usual consumption for auxiliaries, their daily consumption of coal at 12 knots would be about 90 tons instead of 110 tons, which the *Delaware* will now use.

During the last few years the economy and reliability of the turbine has been considerably improved, and the design of the reciprocating engine also gives promise of some advance in economy. The combination system also has been tested out in several variations, notably on large merchant vessels, and in every case economy far in excess of that promised has been realized. If we are after economy and increased steaming radius in our battleship machinery, then certainly we should use the combination instead of again taking up the plain reciprocating engine. In connection with the matter of reliability of turbines, it may be stated that practically all cases of blade stripping in Parsons turbines are confined to the cruising units, and the L.P. turbine has a record for reliability unequaled by the cylinders of the reciprocating engine.

If, on the other hand, we wish ease of operation, freedom

from vibration, less need for continuous overhaul, better operating conditions, greater ability for continuously maintaining high speed, and longer life to our boilers, and we do not care much for special economy below 14 knots, we should have turbines of a design and construction that is susceptible of reasonable ease in examination and overhaul, and should provide in our vessels arrangements that will enable the most economical turbine to be installed. In any case, under present conditions and judging from our present experience, the straight reciprocating engine is at a disadvantage to both the all-turbine or the combination system for large, high-powered vessels.

In the case of merchant vessels of over 10,000 H.P. it certainly looks like folly to install straight reciprocating engines which give a water consumption of not less than 13 pounds of water per horsepower when the combination can deliver a horsepower on 9 pounds of water.

GEARED TURBINES.

The geared turbine is forcing itself to be recognized as a competitor in the marine field. Several gears have been tried, both in this country and abroad, and as far as the operation of the gear is concerned it has been generally successful.

The trials of the *Cairnoss*, in England, and those of the *Neptune*, in this country, have demonstrated that the gearing is apparently a feasible, practical proposition for marine work. High economy in actual practice has not yet been realized.

It is, however, claimed that by the use of superheat on a high-speed geared turbine an economy of 11 pounds of water per S.H.P. can be secured for units of 6,000 to 8,000 horsepower. This is somewhat better than can be accomplished with the directly-connected turbine, especially when it is considered that there will be at least 5 per cent. increase in propeller efficiency.

On the steamship *Cairnoss* an economy of 14 pounds of water per S.H.P. was secured. The combination for same power and steaming pressure used would secure an economy of about 12 pounds of water per S.H.P.

From all indications it would appear that the high-speed geared turbine would not give as good economy by 10 per cent. as the combination turbine will give, but the geared turbine would save a great deal of weight.

If we can accept the gearing as a thoroughly practical and dependable proposition, the geared turbine offers special advantages in the matter of reduction of building cost and space required. If geared turbines are used, the condenser can be placed immediately beneath the turbine in the turbine foundation. This will accomplish a saving of space and weight and does away with all exhaust piping.

The facility for examining rotor will be excellent, since the casings are comparatively small and the top half need have no steam-pipe connections whatever. For the high-speed turbines the parts are comparatively small and the renewals and replacements can easily be made.

If the gearing can be accepted as being sufficiently tried and reliable for use on battleships, it would appear more desirable to use geared turbines instead of directly-connected ones, since there is likely to be some advantage in simplicity, ease of manipulation, overhaul and installation, not to speak of a material saving of weight and cost.

The two systems of geared turbines in the field are the Parsons, in which an independent high and a low-pressure turbine are employed, and the Westinghouse-Parsons, in which the whole range is in one casing. Of these the Westinghouse-Parsons is the simpler.

FUTURE POSSIBILITIES.

Going further into the matter of future possibilities, there is a possible combination that will, perhaps, beat anything, granting that the units of the apparatus proposed will soon be developed to a practical operating basis.

This proposition would consist of the electric-motor drive on the shafts with the current supplied partly by Diesel engines and partly by steam turbines. In this case there

would be several generating units of each type. The exhaust from the oil engine could be utilized to assist in the generation of steam in the boilers, and the feed water for boilers might be used as the cooling water for the oil engine. Such a combination would permit of very great economy and would at the same time enable the propellers to be operated by either the oil engine or the steam engine.

In an oil-engined ship a small steam plant would, in any case, be required for evaporating and heating, so that there is no great increase in complication. The turbines would, of course, weigh much less than the Diesel engine of the same power.

The parts required are an entirely reliable oil engine that can be operated satisfactorily on ordinary fuel oil, either asphalt or paraffine base, and satisfactory development of the electric motor for propulsion. Both of these things may apparently be secured within a few years.

By having six or eight separate Diesel units the cylinders and the other parts of the engine could be of such size that sufficient height could easily be secured, and that satisfactory cooling could be obtained, one or more units could be shut down at any time to receive the necessary cleaning and overhauling.

As arrangements for backing Diesel engines add considerable to complication, it may easily be possible that the motors will weigh less than would the backing arrangements that would have to be added to the Diesel directly-connected unit.

ECONOMY OF AUXILIARIES.

The auxiliaries on a battleship require from 15 to 25 per cent. of the fuel when underway, and their economical operation has a most important bearing on the total fuel consumption, because they are continually in operation.

The principal services are the electrical plant and the evaporator plant. These two services make up about two-thirds of the port consumption.

The electric generators are now driven by steam turbines, usually units of about 300 kw. capacity.

In their operation, the principal method of securing economy lies in maintaining a high vacuum. In some recent vessels augmentors have been installed on the dynamo-room condensers, and by their use a high vacuum, between 28 and 29 inches, can be carried.

The usual electric load on a large battleship is about 100 kw., hence if 300 kw. machines are supplied, they are operated at about one-third power, which is not an economical point.

It would therefore seem advisable to install two smaller units of about 150 kw. each to take the ordinary load.

As far as the operation of dynamos is concerned, it seems that much greater economy would result if these were operated by Diesel oil engines. The Diesel engine will use less than one-half the oil fuel that the steam generator would require.

EVAPORATING PLANT.

The average amount of water required to be distilled for make-up feed and ship's use on a Dreadnought will be about 18,000 gallons per day; about 4,000 gallons being required for make-up feed and 14,000 gallons for ship's use.

With double-effect evaporators fitted with vapor feed heaters, and H.P. coil-drain heaters, operated in a careful manner, this amount of water can be distilled on an expenditure of about 6 tons of coal per day. Results approximating this are actually being obtained in some cases. By making evaporators in triple or quadruple effect the expenditure could be reduced to about 4.5 to 5 tons per day. Arrangements could also be made for using the auxiliary exhaust for distilling in port, whereby considerable further saving might be possible. A quadruple-effect plant of Lillie type would require only about 3 tons per day.

ELECTRIC PLANT.

With Diesel engines 2,400 kw. hours should not require more than 2,000 pounds of oil, or an equivalent of 3,000 pounds of coal.

Our present turbo generators of 300 kw. capacity and their necessary auxiliaries call for an expenditure of about 4.5 tons of coal for 2,400 kw. hours.

It will thus be seen that the use of the Diesel engine for the electric plant carries with it the possibility of saving about 2½ tons of coal per day on each large battleship. This appears to be about the largest saving that can be made in the auxiliary consumption.

GALLEY AND BAKERY.

The galley and bakery, besides the steam required for heating, will, on a large vessel, call for about 1,200 pounds of coal per day. By use of electric galley and bake ovens this expenditure will be about the same.

REFRIGERATION.

This consists of the cold storage and the refrigeration of magazines. With dense-air ice machines it will require about 1,200 pounds of coal per day for each three-ton machine operated. Ordinarily, unless in quite warm weather, two three-ton machines will perform the service, maintaining magazines well below 90 degrees F. and keeping down cold storage and furnishing about 800 pounds of ice per day.

It is believed, however, that chemical refrigerating machines, ammonia, CO_2, etc., would be considerably more economical, especially for magazine refrigeration. These can be electrically driven and, considering the good economy of the electric generator proposed, will result in a considerable saving over the steam-driven dense-air machine.

HEATING SERVICE.

This service in cold weather requires a very considerable amount of fuel. On a large vessel, in real cold weather, about 4 tons of coal per day would be required. Ordinarily there is some fuel used for this service for heating water in pantries, baths, etc., but the water-heating service will, however, not call for any great expenditure.

PUMPING, FLUSHING, ETC.

This is a variable demand, and it is estimated that from 1 to 3 tons of coal per day are used for this purpose.

AIR–COMPRESSING PLANT.

When this is used for cleaning boilers, operating tools, foundry, forge, etc., an appreciable amount of fuel is used, especially since the air compressors, being small units, are quite wasteful. The average consumption, considering that two 11-inch compressors are used 10 hours each day, will run about 1 ton per day.

Electrically-driven compressors of fewer number and larger unit capacity would, no doubt, be more economical, and by their use another small reduction in steam consumption is possible.

SHIP'S BOATS.

The fuel consumption of the ship's boats is, of course, quite variable, depending on the amount of running and on the condition of the machinery. For ordinary service, a 40-foot steamer will use 600 pounds of coal per day, and the 50-foot steamers will burn about 1,000 pounds per day. Three steamers will, therefore, average about 1 ton per day.

We have, therefore, the following daily consumption possible:

	Tons.
Evaporating,	6.0
Galley,	.5
Steamers,	1.0
Electric power, oil equivalent to coal,	1.4
Pumping, etc.,	2.5
Air compressors,	1.0
Ice machines,	1.0
Total,	13.4
For heating in cold weather and allowance for refrigeration,	2.5
Grand total,	15.9

The present average port consumption for large vessels runs at about 25 tons per day. Some of the large vessels get down to about 20 tons per day and occasionally to 18 tons.

There can be no question that our large vessels can be brought down to a daily consumption of about 14 tons per day, if present knowledge in the matter of installation and operation is used to the very best advantage and reasonable care is exercised to see that there is no waste of fresh water or electric power.

THE CUMMINGS ENGINE LOG SYSTEM AND REVOLUTION COUNTERS.

By H. R. Gary, Associate.

The inventor* of this system, as installed on the U. S. S. *Arkansas,* has taken advantage of the uniform slip of the propellers at any given speed and developed instruments to transfer the revolutions of the propellers to distance traveled through the water.

Plate 1 shows a type plan of the installation. A copper tube is connected to the main condenser, having a branch to the auxiliary condenser, which leads to a rotary valve attached to the average counter shaft and on to the stop clock and engine log, the names adopted for these two instruments. Both the stop clock and engine log contain a cylinder in which moves a piston; so that when the valve opens permitting air in pipe from counter to instruments to become rarefied by the suction of the vacuum the piston, having atmospheric pressure on top and a partial vacuum beneath, moves downward and in so doing it starts or stops, as will be seen later, the hand of the stop clock and moves the counter in the engine log.

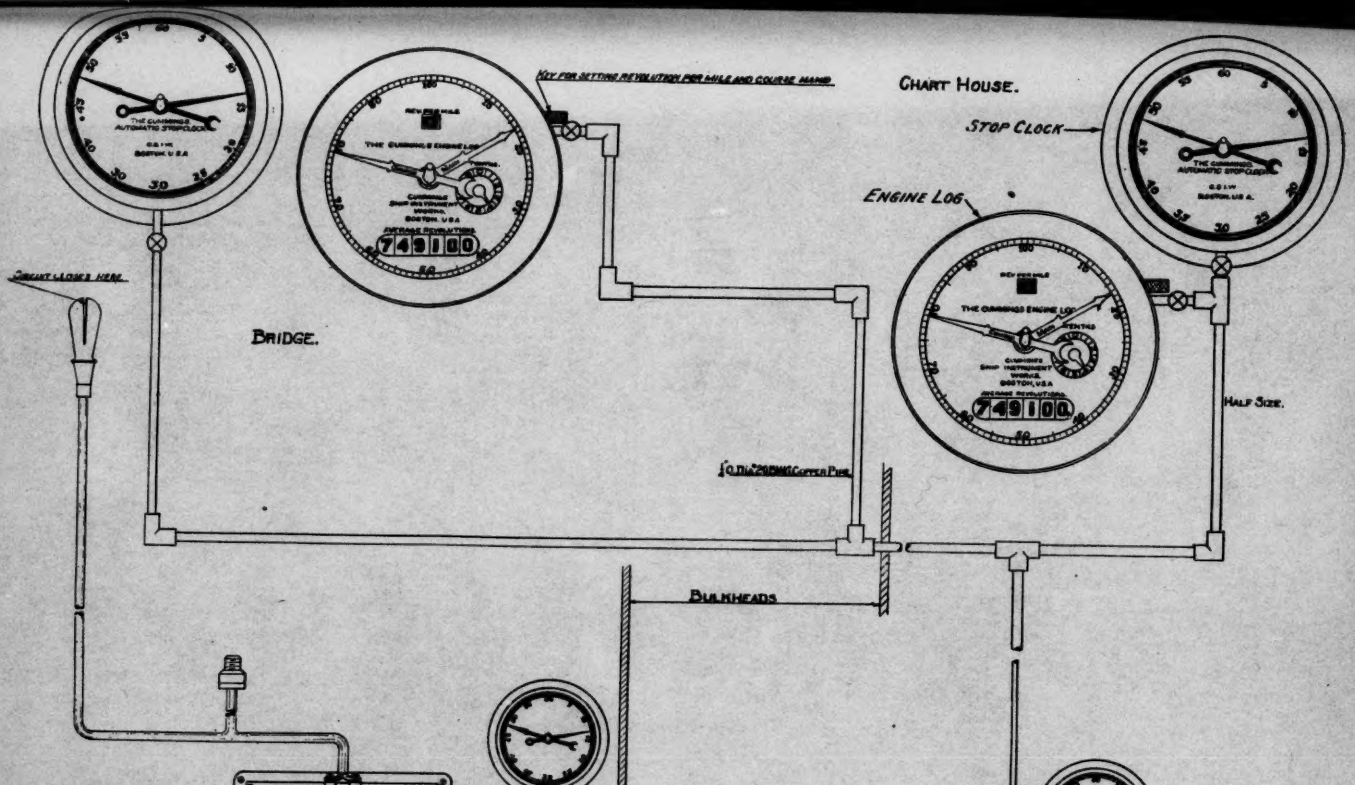
ENGINE LOG.

Plate 2 shows an outside view of the engine log and Plate 3 its interior. When a vacuum is created in the pipe it causes the piston, shown in cylinder on left side of case, to move downward, this causes the extreme right-hand number wheel to advance one number; thus the average counter reading in engine room is reproduced on bridge, chart house, and as many places on ship as desired to locate the instruments.

* Mr. Henry H. Cummings.

The rotary valve shown attached to counter in Plate 1 revolves once to each two hundred average revolutions of engines, but the opening, being entirely through the revolving part, opens the line between condenser and instruments each 100 turns and creates a vacuum in pipe. This valve also has two ports that admit air to pipe on the instrument side which permits the pistons in the instruments to assume normal position.

Since the valve opens each 100 revolutions of engines, the counter reading is the number of 100 turns made. Two ciphers shown on Plate 2 are to avoid confusion. To the right of the number wheels is shown a carborundum wheel which is carried on same shaft that operates counter and actuates a copper disc that in turn moves the hands which indicate the distance traveled. The instrument is shown set to 872 revolutions per mile, so that the hand showing tenths makes one complete revolution to each 872 average revolutions of engines. The hand marked "Main" is geared to tenths hand so that it moves one division to each revolution of the latter. The hand marked "Course" is carried by friction with main hand, and may be set at any time to zero without disturbing reading of other hands by applying square-ended key shown on right of counter through glass cover. This was added so that on passing any known point the course hand could be set to zero, then its reading at a glance will show the distance from that point without the usual calculations. When speed of ship is changed, or for any other reason the revolutions per mile vary, the ratio may be changed so that corrections to readings are unnecessary. By unlocking counter the carborundum wheel is drawn away from copper disc so that the disc may be moved to and from center of wheel without wearing a flat on it. The same movement, *i.e.*, turning of key, throws out a pin that fits in the gear attached to small counter which indicates revolutions per mile, thus unlocking it so that the ratio may be changed; this movement also disengages a lock on case cover which will allow cover to be unscrewed. Thus it is seen that when the counter is locked nothing can be


Key for setting revolution per mile and course hand
Chart House.
Stop Clock
Engine Log
Bridge.
Half Size.
Bulkheads

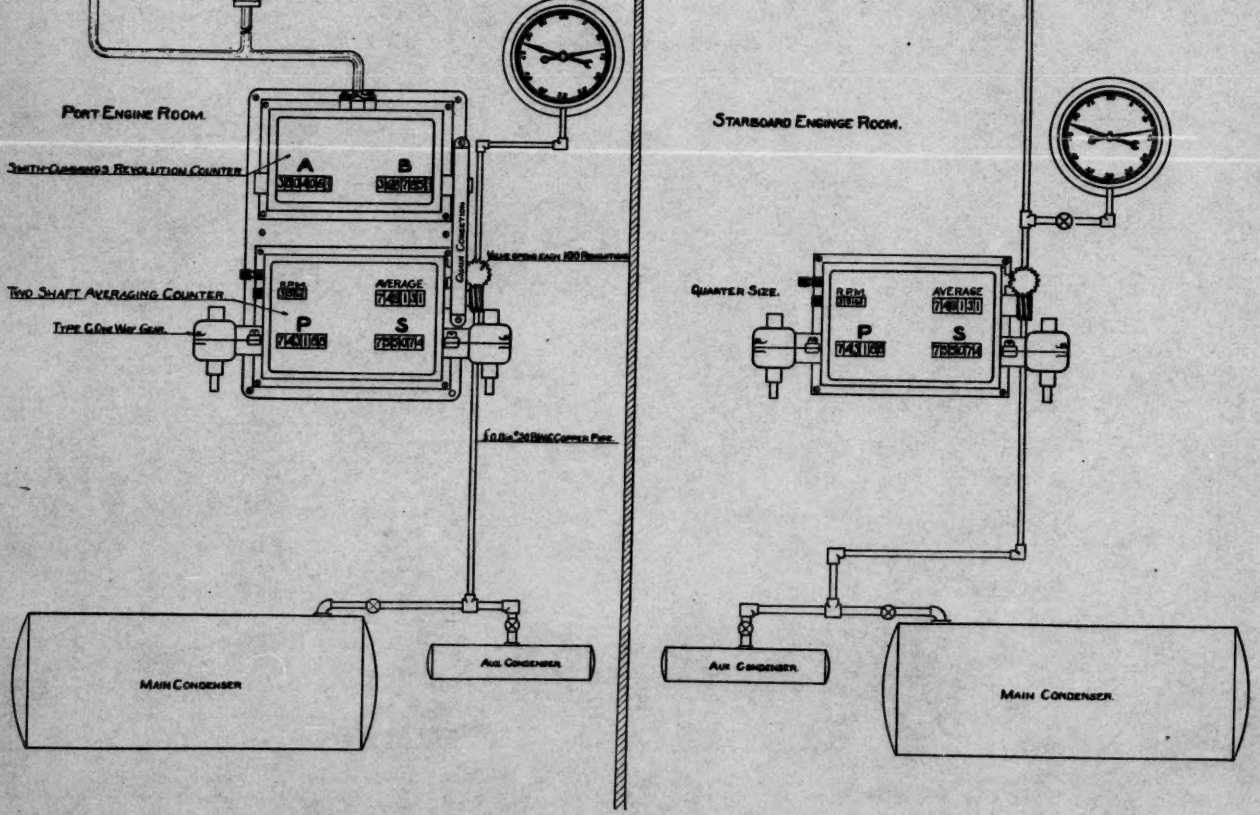

PORT ENGINE ROOM.
SMITH-CUMMING'S REVOLUTION COUNTER
A
B
TWO SHAFT AVERAGING COUNTER
TYPE C ONE WAY GEAR.
R.P.M.
AVERAGE
P
S
VALVE OPENS EACH 100 REVOLUTIONS
QUARTER SIZE.
MAIN CONDENSER
AUX. CONDENSER
STARBOARD ENGINGE ROOM.
AUX. CONDENSER
MAIN CONDENSER.

PLATE I.

disturbed except course hand. Suppose it was known that under present conditions the ship moved one mile for each 920 average revolutions of engines, then the key at right of case is turned until the small counter reads 920; this causes a wedge-shaped yoke fitted on threaded spindle to move to the left, and the wedge pushes the spindle which carries the copper disc toward center of wheel against the action of a spring. When the counter reads 920 the disc is at the proper distance from center of wheel to move tenths hand one turn for each 920 of engines. When case is locked the wheel is allowed to come in contact with disc and held so by a spring, the gear actuating under "Rev. Per Knot" is locked so that disc cannot be dragged over wheel and the case cover is locked to prevent unscrewing. Thus it is seen that the usual calculations necessary to determine distance traveled are mechanically performed each 100 turns of engines and the possibilities of personal error eliminated. The accuracy of this instrument, besides the navigator's ability to estimate revolutions per mile, depends entirely upon the ratios between carborundum wheel and copper disc, and it is surprising to know how accurate the arrangement is. Shop tests at all different speeds and lasting for nearly two months failed to show any appreciable error. This is due, perhaps, to the very little work performed by the disc, its slow movement, thinness, and the provision to remove it from contact when changing ratio.

STOP CLOCK.

Plate 4 shows a view of the stop clock, the mechanism of which is the same as an ordinary stop watch. A pipe connects the stop clock with the main (or auxiliary) condenser, and the rotary valve previously mentioned opens this pipe to the condenser every 100 turns of the main engines. The vacuum in the connecting pipe causes the piston (similar to that on engine log) to descend, thereby starting the second hand. The vacuum in the pipe is broken as soon as the rotary valve shuts off the connection to the condenser, air being admitted

to the pipe and spring mechanism causes the piston to resume its original position.

As soon as the engines make 100 turns from the time of starting the clock, the pipe is again opened to the condenser, the piston descends and stops the clock. The reading shows the time to make 100 average revolutions, and by reference to Table I, the revolutions per minute can be quickly determined. For example, if the clock stops on 47.8 seconds, the revolutions per minute are 125.5. The second hand remains where it was stopped until the piston has attained its normal position, when it is released and goes back to zero. This takes an appreciable time, so that the throttle man can easily see what speed he is making. During the next 100 revolutions from the stopping of the hand, the hand goes back to zero and is in position to repeat the cycle. The cycle is repeated every 200 revolutions. A movable index (not shown) is fitted to the face of the clock, and this is set at the time required to make 100 revolutions to give the necessary revolutions per minute. Suppose it is desired to make 163 r.p.m., then by consulting Table I, the time to make 100 revolutions at this speed is seen to be 36.8 seconds. The index is then placed at 36.8, and when the second hand stops exactly at the index the engines are making 163 average revolutions per minute.

REVOLUTION COUNTERS.

The two-shaft averaging counter contains three counters, one for the starboard revolutions, one for the port revolutions, and one for the average of the two, connected in the usual way to the main shafts through a combination of gears and ratchets that drives the following shaft in one direction regardless of direction of rotation of driving shaft, the trade name of which is "One-way Gear." By the introduction of this one-way gear the counters are made to register ahead when engines are running astern, at the same time eliminating the troublesome reciprocating motion.

Each instrument will be described in detail to give a more

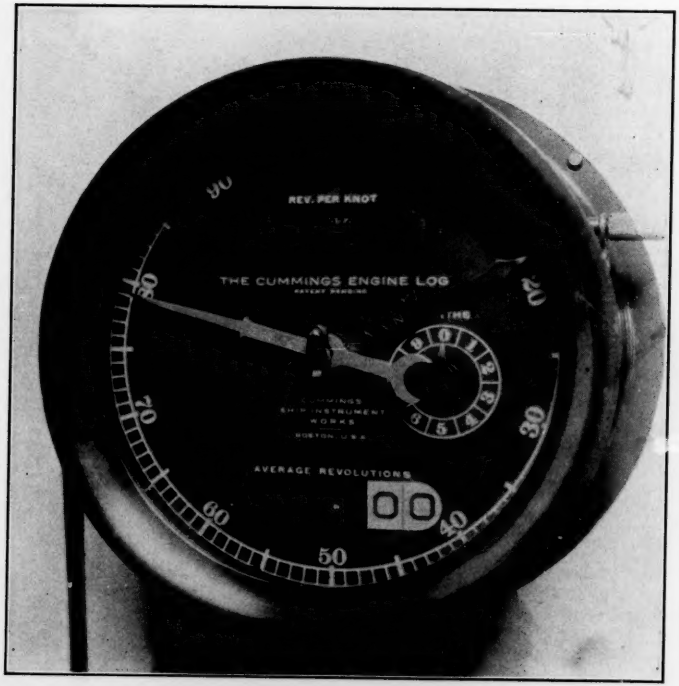


PLATE 2.

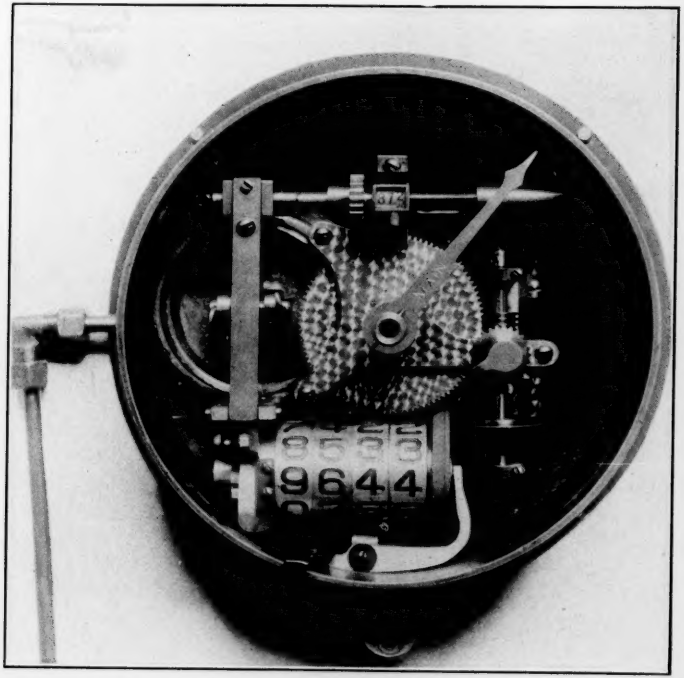


PLATE 3.

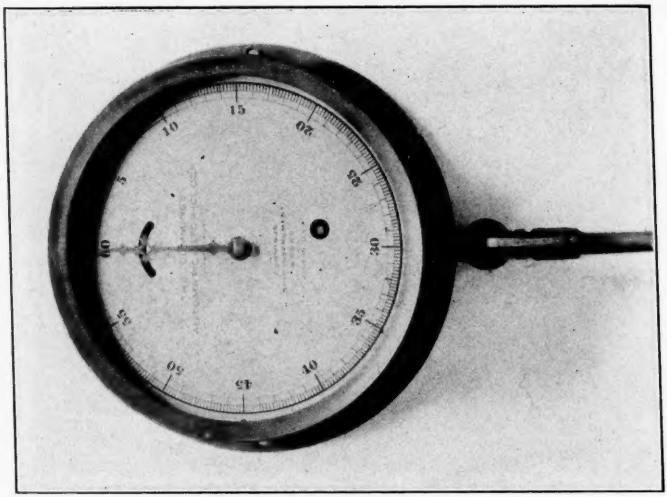


PLATE 4.

14	428.6	**21**	285.7	**28**	214.3	**35**	171.5	**42**	142.9	**49**	122.5	**56**	107.1	**63**	95.3	**70**	85.7
.2	422.5	.2	283.	.2	212.8	.2	170.5	.2	142.2	.2	122.	.2	106.8	.2	95.	.2	85.5
.4	416.7	.4	280.4	.4	211.3	.4	169.5	.4	141.5	.4	121.5	.4	106.4	.4	94.7	.4	85.3
.6	411.	.6	277.7	.6	209.8	.6	168.5	.6	140.8	.6	121.	.6	106.	.6	94.4	.6	85.
.8	405.4	.8	275.2	.8	208.3	.8	167.5	.8	140.2	.8	120.5	.8	105.6	.8	94.1	.8	84.8
15	400.	**22**	272.7	**29**	206.9	**36**	166.7	**43**	139.5	**50**	120.	**57**	105.3	**64**	93.8	**71**	84.6
.2	394.7	.2	270.3	.2	205.5	.2	165.7	.2	138.9	.2	119.5	.2	104.9	.2	93.5	.2	84.2
.4	389.6	.4	267.9	.4	204.1	.4	164.8	.4	138.2	.4	119.	.4	104.5	.4	93.2	.4	84.
.6	384.6	.6	265.5	.6	202.7	.6	163.9	.6	137.4	.6	118.6	.6	104.2	.6	92.9	.6	83.8
.8	379.7	.8	263.2	.8	201.3	.8	163.	.8	137.	.8	118.1	.8	103.8	.8	92.6	.8	83.6
16	375.	**23**	260.9	**30**	200.	**37**	162.2	**44**	136.4	**51**	117.6	**58**	103.4	**65**	92.3	**72**	83.4
.2	371.	.2	258.6	.2	198.7	.2	161.2	.2	135.7	.2	117.2	.2	103.1	.2	92.	.2	83.2
.4	365.8	.4	256.4	.4	197.4	.4	160.4	.4	135.1	.4	116.7	.4	102.7	.4	91.7	.4	83.
.6	361.4	.6	254.2	.6	196.1	.6	159.5	.6	134.5	.6	116.3	.6	102.4	.6	91.4	.6	82.6
.8	357.	.8	252.1	.8	195.3	.8	158.7	.8	133.9	.8	115.8	.8	102.	.8	91.1	.8	82.4
17	352.9	**24**	250.	**31**	193.6	**38**	157.9	**45**	133.3	**52**	115.4	**59**	101.6	**66**	90.9	**73**	82.2
.2	348.8	.2	247.9	.2	192.3	.2	157.1	.2	132.7	.2	114.9	.2	101.4	.2	90.6	.2	82.
.4	344.8	.4	245.9	.4	191.1	.4	156.3	.4	132.2	.4	114.5	.4	101.	4	90.3	.4	81.8
.6	340.9	.6	243.9	.6	189.8	.6	155.4	.6	131.6	.6	114.1	.6	100.7	.6	90.	.6	81.6
.8	337.1	.8	241.9	.8	188.7	.8	154.6	.8	131.	.8	113.6	.8	100.3	.8	89.8	.8	81.4
18	333.3	**25**	240.	**32**	187.5	**39**	153.8	**46**	130.4	**53**	113.2	**60**	100.	**67**	89.6	**74**	81.2
.2	329.7	.2	238.1	.2	186.3	.2	153.1	.2	129.9	.2	112.8	.2	99.6	2	89.3	2	81.
.4	326.1	.4	236.2	.4	185.2	.4	152.3	.4	129.3	.4	112.4	.4	99.3	.4	89.	4	80.8
.6	322.6	.6	234.4	.6	184.	.6	151.5	.6	128.8	.6	111.9	.6	95.	.6	88.8	6	80.4
.8	319.1	.8	232.6	.8	182.9	.8	150.8	.8	128.2	.8	111.5	.8	98.7	.8	88.5	.8	80.2
19	315.8	**26**	230.8	**33**	181.8	**40**	150.	**47**	127.7	**54**	111.1	**61**	98.4	**68**	88.2	**75**	80.
.2	312.5	.2	229.	.2	180.7	.2	149.3	.2	127.1	2	110.7	.2	98.1	.2	88	2	79.8
.4	309.3	.4	227.3	.4	179.6	.4	148.5	.4	126.6	.4	110.3	.4	97.8	.4	87.7	.4	79.6
.6	306.1	.6	225.6	.6	178.6	.6	147.8	.6	126.1	.6	109.9	.6	97.5	.6	87.4	.6	79.4
.8	303.	.8	223.9	.8	177.5	.8	147.1	.8	125.5	.8	109.5	.8	97.2	.8	87.2	.8	79.2
20	300.	**27**	222.2	**34**	176.5	**41**	146.3	**48**	125.	**55**	109.1	**62**	96.9	**69**	87.	**76**	79.
.2	297.	.2	220.6	.2	175.4	.2	145.6	.2	124.5	.2	108.7	.2	96.6	.2	86.7	.2	78.8
.4	294.1	.4	218.9	.4	174.4	.4	144.9	.4	124.	.4	108.3	.4	96.3	.4	86.4	.4	78.6
.6	291.3	.6	217.4	.6	173.4	.6	144.2	.6	123.5	.6	107.9	6	96	.6	86.1	.6	78.4
.8	288.5	.8	215.8	.8	172.4	.8	143.5	.8	123.	.8	107 5	.8	95.6	.8	85.9	.8	78.2

TABLE I.—REVOLUTIONS PER MINUTE, FROM SECONDS PER 100 REVOLUTIONS.

clear understanding of their functions and also to show how the different results are accomplished.

A two-shaft averaging counter connected to a Smith-Cummings counter is shown on Plate 6 and in port engine room on Plate 1. Plate 5 shows an assembled view of this counter.

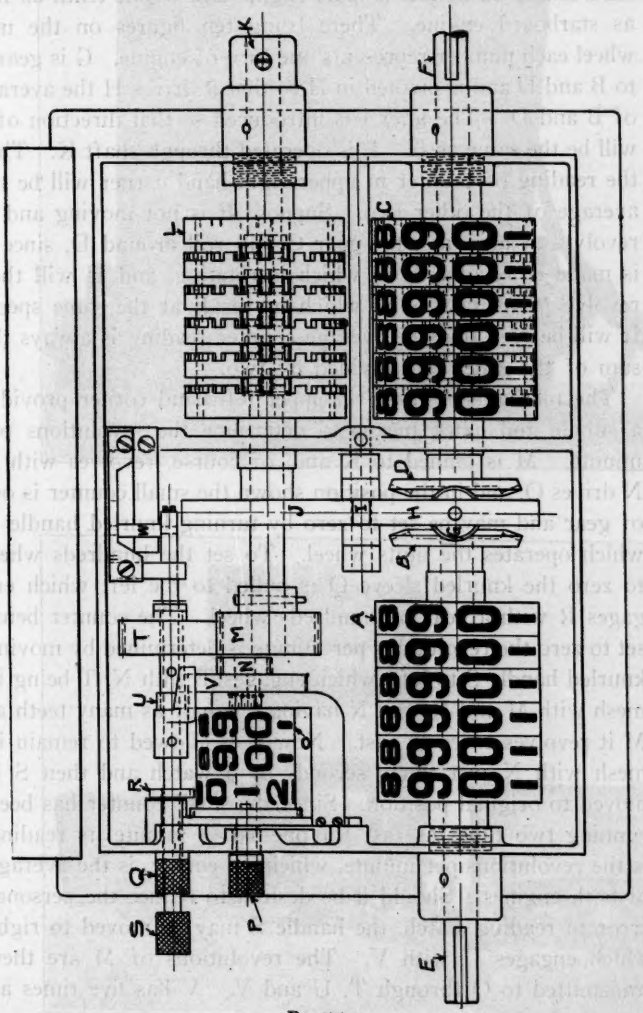


PLATE 5.

The number wheels are mounted on a drum which contains the star wheels on inner side permitting the numbers to appear contiguous. A is connected to B through shaft E, and the motion of C is transmitted to D through F so that B runs one-tenth as fast as port engine and D one-tenth as fast as starboard engine. There being ten figures on the unit wheel each number represents one turn of engine. G is geared to B and D and is pivoted in H so that it drives H the average of B and D. The idler I is introduced so that direction of J will be the same as H. L is operated through shaft K. Thus the reading of counter in upper right-hand corner will be the average of the other two. Suppose F is not moving and E revolves at any rate, the gear G will roll around D, since it is made to revolve by B which is rotating, and H will then revolve ½ as fast as B, which moves L at the same speed. It will be seen that the average counter reading is always the sum of the other two divided by two.

The mechanism shown in upper left-hand corner provides a simple and quick means to determine the revolutions per minute. M is pinned to K and, of course, revolves with J. N drives O, and in the position shown the small counter is out of gear and may be set to zero by turning knurled handle P which operates the units wheel. To set the hundreds wheel to zero the knurled sleeve Q is pulled to the left which engages R with a gear on hundreds wheel. The counter being set to zero the revolutions per minute is determined by moving knurled handle S to left, which engages T with N, T being in mesh with M and N, and N having one-half as many teeth as M it revolves twice as fast. Now T is allowed to remain in mesh with N just thirty seconds by a watch and then S is moved to original position. Since the small counter has been running two times as fast for one-half a minute its reading is the revolutions per minute, which, of course, is the average of both engines. Should it be desired to reduce the personal error in reading watch, the handle S may be moved to right which engages U with V. The revolutions of M are then transmitted to O through T, U and V. V has five times as

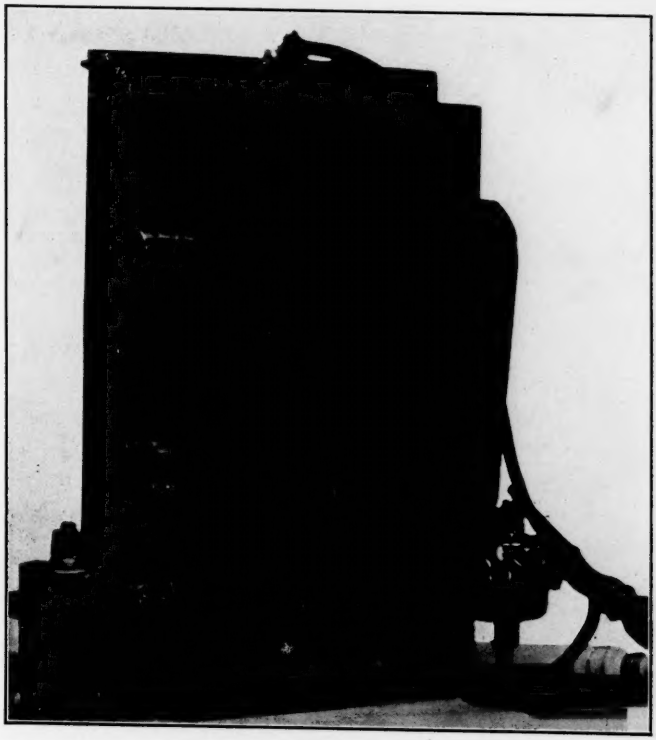


PLATE 6.

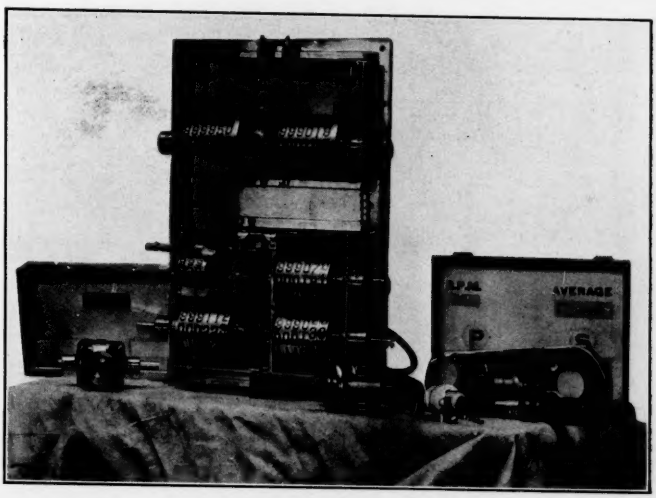


PLATE 7.

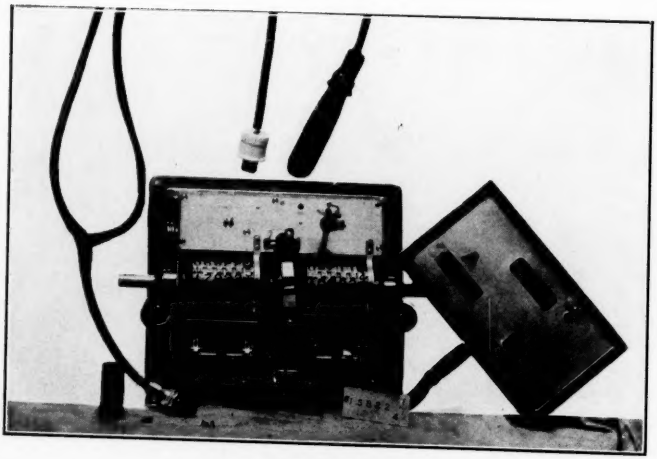


PLATE 8.

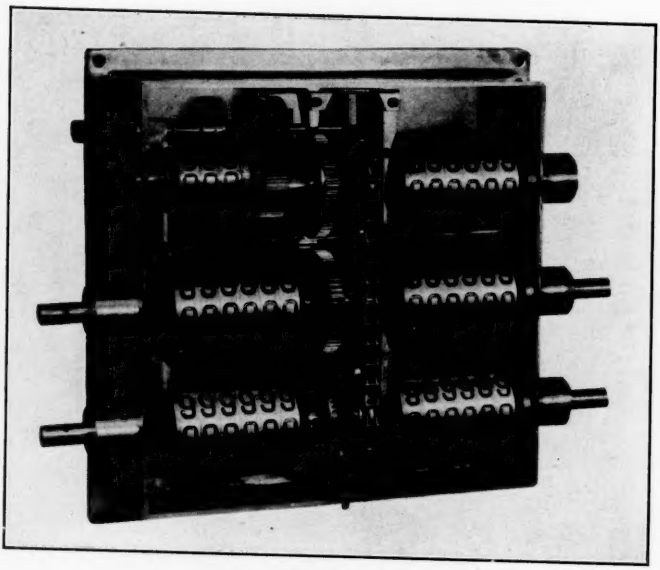


PLATE 9.

many teeth as U, T and M the same number, so V moves one-fifth as fast as M. Then if U is allowed to stay in mesh with V for five minutes the reading will be the average revolutions per minute for a period of five minutes. W is merely a pin that works in notches to prevent throwing other gear in mesh when one gear is being thrown out. The ends of the gear

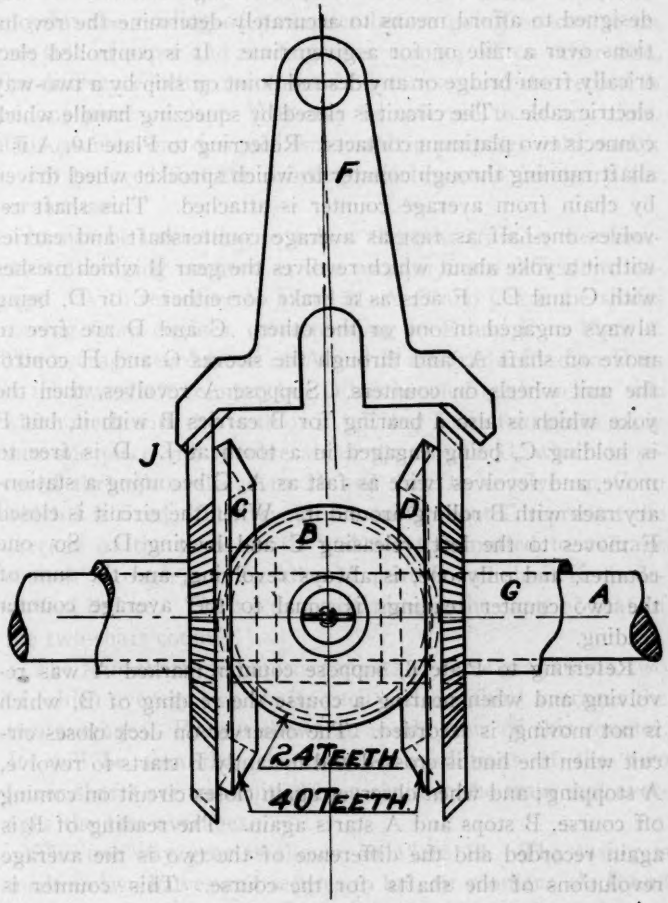


PLATE 10.

teeth are sharpened so that the gears will always go in mesh. An examination of Plate 7 will show, perhaps, more clearly the construction of this r.p.m. attachment.

The Smith-Cummings counter is connected by a chain, shown on Plate 7, to average shaft of averaging counter in the ratio of 1 to 2, but is geared up again, so that moving counter moves at the same rate as average counter. It was designed to afford means to accurately determine the revolutions over a mile or for a given time. It is controlled electrically from bridge or any desired point on ship by a two-way electric cable. The circuit is closed by squeezing handle which connects two platinum contacts. Referring to Plate 10, A is a shaft running through counter to which sprocket wheel driven by chain from average counter is attached. This shaft revolves one-half as fast as average countershaft and carries with it a yoke about which revolves the gear B which meshes with C and D. F acts as a brake for either C or D, being always engaged in one or the other. C and D are free to move on shaft A, and through the sleeves G and H control the unit wheels on counters. Suppose A revolves, then the yoke which is also a bearing for B carries B with it, but F is holding C, being engaged in a tooth at J. D is free to move, and revolves twice as fast as A, C becoming a stationary rack with B rolling around it. When the circuit is closed F moves to the left, releasing C and locking D. So one counter, and only one, is always revolving, and the sum of the two counter readings is equal to the average counter reading.

Referring to Plate 6, suppose counter marked A was revolving and when nearing a course the reading of B, which is not moving, is recorded. The observer on deck closes circuit when the line is crossed and instantly B starts to revolve, A stopping; and when observer again closes circuit on coming off course, B stops and A starts again. The reading of B is again recorded and the difference of the two is the average revolutions of the shafts for the course. This counter is equally useful in determining the revolutions for each period

during a long run, as first A then B is recorded as each stops, and from their readings the revolutions may be accurately determined.

Plate 8 shows a Smith-Cummings counter fitted up to print the readings. Each counter may be read or the reading may be printed on a piece of blotting paper which eliminates the possibility of error in reading. It has been found convenient to print the reading of a counter before going on course on one side of paper and reading after coming off on other side, the difference being revolutions on course, and the record is on one piece of paper that may be referred to at any time. This counter was designed for trial-trip purposes only, and it is not believed that the printing attachment is necessary for service use.

It may be interesting to follow the gear train in the three-shaft averaging counter, as this was far more difficult to design. With reference to Plate 11, A, B and C are the shafts coming from engines, corresponding to E and F in Plate 5. The average revolutions of A and B are transmitted to D as in the two-shaft counter, but D has beveled teeth on one side which mesh with the teeth of E. E and F are two gears made into one piece and revolve about the spindle G, which is secured through a sleeve to H and free to revolve on C to which I is fixed. The revolutions of G about C represent the average of the three shafts and are transmitted to average counter through gear H, idler M, gear J, and shaft K, as described before. The r.p.m. mechanism is the same as that of the two-shaft counter.

The four-shaft mechanism consists of three gear trains, two of which average two shafts each and the third averages the two averages. Plate 9 shows an inside view of this counter. It will be seen that the average revolutions of the two lower shafts are transmitted by a chain to the train that averages the two averages.

The one-way gear is shown on Plate 12. The casing is made in two halves and secures to hub on counter. A, B and C are beveled gears and D the driving shaft, the following

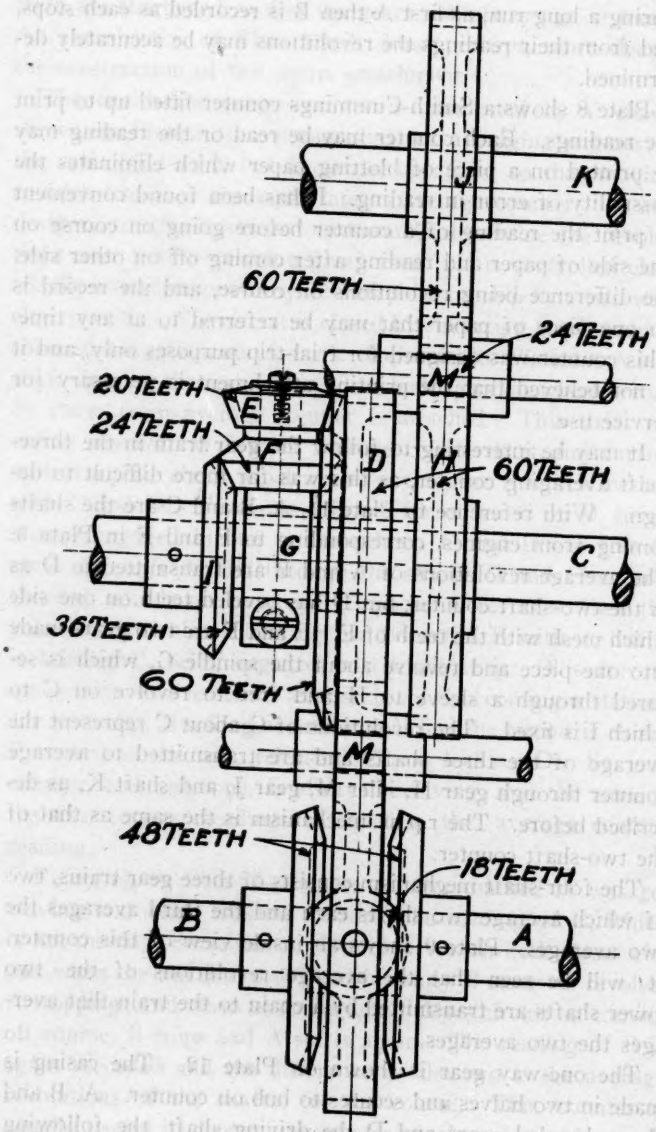

K
J
60 TEETH
24 TEETH
M'
20 TEETH
E
24 TEETH
F
D
H
60 TEETH
G
C
36 TEETH
60 TEETH
M
48 TEETH
18 TEETH
B
A

PLATE II.

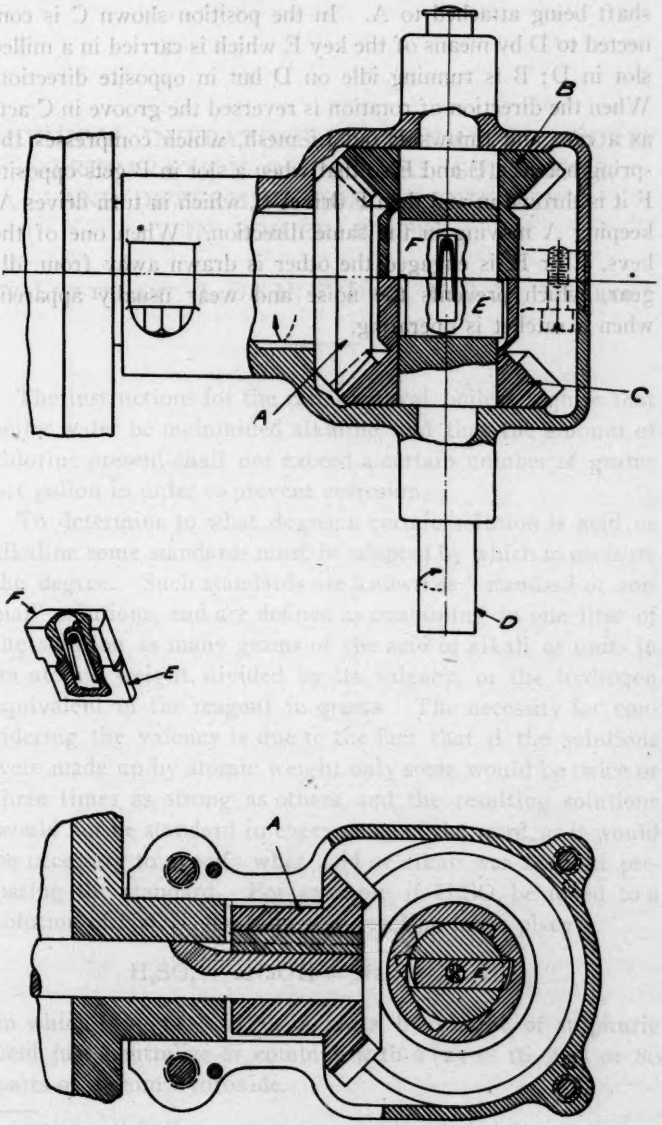
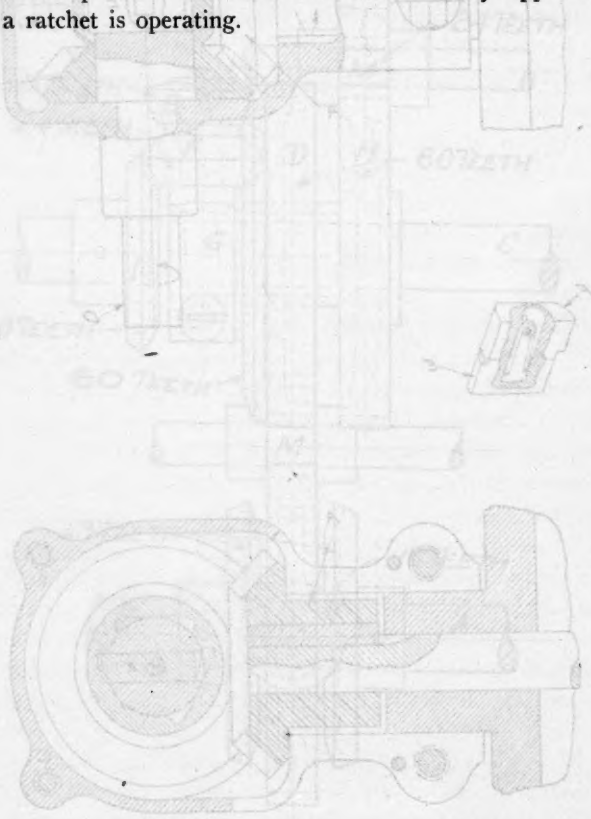


PLATE 12.

shaft being attached to A. In the position shown C is connected to D by means of the key E which is carried in a milled slot in D; B is running idle on D but in opposite direction. When the direction of rotation is reversed the groove in C acts as a cam and throws E out of mesh, which compresses the spring between E and F so that when a slot in B gets opposite F it is thrown in and then F drives B, which in turn drives A, keeping A moving in the same direction. When one of the keys, E or F, is engaged the other is drawn away from idle gear, which prevents the noise and wear usually apparent when a ratchet is operating.



CHEMICAL INDICATORS IN VOLUMETRIC WORK. —PREPARATION OF NORMAL SOLUTIONS, AND DETERMINATION OF CHLORINE IN BOILER WATER.

By Lieutenant (J. G.) H. T. Dyer, U. S. N., Member.*

The instructions for the care of naval boilers require that boiler water be maintained alkaline, and that the amount of chlorine present shall not exceed a certain number of grains per gallon in order to prevent corrosion.

To determine to what degree a certain solution is acid or alkaline some standards must be adopted by which to measure the degree. Such standards are known as "standard or normal" solutions, and are defined as containing in one liter of the solution as many grams of the acid or alkali as units in its atomic weight, divided by its valency, or the hydrogen equivalent of the reagent in grams. The necessity for considering the valency is due to the fact that if the solutions were made up by atomic weight only some would be twice or three times as strong as others, and the resulting solutions would not be standard in every sense of the word, as it would be necessary to specify what acid or alkali was used in preparing the standard. For example, if H_2SO_4 be added to a solution of NaOH, the following reaction takes place:

$$H_2SO_4 + 2NaOH = Na_2SO_4 + 2H_2O,$$

in which $(2 + 32 + 64)$ or 98 parts, by weight, of sulphuric acid just neutralize or combine with $2\ (23 + 16 + 1)$ or 80 parts of sodium hydroxide.

* Talk delivered before the post-graduate students, U. S. Naval Academy, Annapolis, Md.

If, instead of using sulphuric acid, hydrochloric acid is used, the following reaction takes place:

$$HCl + NaOH = NaCl + H_2O,$$

and 36 parts by weight of HCl neutralize 40 parts of NaOH.

The valency of an acid being defined as the number of replaceable hydrogen atoms it contains; of an alkali, the number of hydrogen atoms that have been displaced from water by a metal; and of salt, the number of hydrogen atoms in the acid from which the salt was made, normal or standard solutions can be prepared if the atomic weights and valencies of the acid, alkalis or salts are known.

For accuracy in determining the degree of acidity or alkalinity of weak solutions, the standard solutions may be made in fractional strengths, 1/5, 1/10, 1/50, etc.

In determining, for example, the alkalinity of an unknown sample, it is neutralized by a solution of known acidity, and in order to determine the exact point of neutralization, some means, as a sudden change of color of the solution, must be provided.

This change of color may be produced by the addition to the solution of another substance, known as an indicator, which is not acted upon until the neutralization is complete.

The most common indicators are litmus, methyl orange and phenol phthalein, all of which are used on board ship in determining the acidity or alkalinity of boiler water. Potassium chromate is also used in connection with silver nitrate in determining the number of grains of chlorine in the water.

Litmus, the most common indicator, is the coloring matter of a certain plant, and when prepared for use is turned red by an acid and blue by an alkali.

When an alkaline carbonate is being titrated against an acid, or vice versa, CO_2 is liberated and forms with the water of the solution a weak acid, which acts upon the litmus, and hence gives a wrong indication of the neutral point. This difficulty may be obviated by keeping the solution boiling during titration, thus expelling the CO_2. Also SO_2, CrO_3,

organic acids and salts of iron and aluminum affect the litmus and render its use unsatisfactory.

Methyl orange is a very complex salt, which is prepared for use by dissolving in water, and in neutral and alkaline solutions is yellow, but pink in acid solutions. It is unaffected by CO_2 in moderate amounts, but is a poor indicator for use with organic acids. Oxalic acid or oxalates decompose and render it useless, and to ferric or alumnic salts and calcium bisulphate it is neutral. To obtain the best results, small amounts only should be used, and in cold solutions.

Phenol phthalein is a coal-tar product, which is dissolved in alcohol and water when prepared for use as an indicator. In the presence of acids or in a neutral solution it is colorless, but bright red in the presence of alkalies. It is useless with ammonia or its salts, is sensitive to CO_2 and H_2S, and neutral to acid carbonates.

In addition to using these indicators in solution, test papers may be prepared by saturating sheets of paper (filter paper is preferable) with slightly ammoniacal solutions of the indicator. Upon drying, the ammonia evaporates, leaving the color in proper condition.

The normal solutions most frequently used are H_2SO_4, Na_2CO_3, NaOH, and KOH. If a standard solution is available to titrate against, the preparation of the solutions is comparatively simple; if not, a standard must be established, and the other solutions titrated against it.

Sodium bicarbonate, $NaHCO_3$, can be obtained chemically pure almost anywhere, and from it chemically pure sodium carbonate, Na_2CO_3, can be obtained quite readily; hence it will be found the easiest with which to start. NaOH and KOH can be obtained chemically pure, but they are very hygroscopic, and even if obtained without any water will pick up moisture from the atmosphere during weighing and so cause inaccuracies in the results. The acids are difficult to obtain pure and all will contain an uncertain amount of water, and hence cannot be considered in establishing a standard. A normal solution of Na_2CO_3 should contain 53 grams of Na_2CO_3 per liter.

$$Na_2 = 23 \times 2 = 46$$
$$C = 12$$
$$O_3 = 16 \times 3 = 48$$
$$106$$

$$\text{Valency} = 2 \quad \therefore \quad \frac{106}{2} = 53.$$

Eighty-four grams of bicarbonate should yield about 53 grams of normal carbonate; so to prepare a liter of the solution, slightly more than 84 grams of bicarbonate must be employed.

Place this amount in a clean, weighed platinum dish and heat to a dull red, for 10 or 15 minutes, taking care that the salt is not fused. The CO_2 and H_2O are driven off by this means. It is then cooled in a dessicator and weighed. To ensure that the decomposition has been completed, the dish is heated for another 10 minutes and, after cooling in the dessicator, weighed again. If the weight is same as before, the decomposition is complete. If not, the dish and contents must be again heated, cooled and weighed, and this process repeated until no further decrease in weight is noted, when pure Na_2CO_3 will be obtained.

A liter flask should now be fitted with a funnel, and into the funnel poured about 53 grams of the Na_2CO_3. The remainder is then weighed and the exact amount put in the funnel determined. Suppose the platinum dish to weigh 500 grams, the dish plus the Na_2CO_3 to weigh 560 grams. An amount of Na_2CO_3 estimated to weigh about 53 grams placed in the funnel. The dish and contents are then weighed and found to be 506 grams. Fifty-four grams of Na_2CO_3 has been put in the funnel. This must now be very carefully washed through the funnel into the liter flask with distilled water, the flask filled to the liter mark, and the whole thoroughly mixed by shaking. As 53 grams per 1,000 c.c. is the strength desired, $\frac{54}{53} \times 1{,}000$ or 1,018.87, should be the total amount of solution,

so that after filling the flask to the liter mark 18.87 c.c. of water should be added; or after first filling to the liter mark, there are 54 grams of Na_2CO_3 dissolved in the liter of distilled water, and but 53 grams are desired. So in $\frac{53}{54}$ of 1,000 c.c., or 981.48 c.c., there will be 53 grams of Na_2CO_3. Therefore, (1,000—981.48) or 18.52 c.c. of the solution are removed, and the flask again filled to the liter mark, and there are now 53 grams of Na_2CO_3 dissolved in 1,000 c.c. of water and the solution is of normal strength.

The exact amount, 53 grams, might have been weighed out, but this would have required very careful weighing and the expenditure of a considerable amount of time, and during the weighing the salt would have been absorbing moisture from the atmosphere, so that the first method is considered preferable.

Having now a normal alkaline solution, a normal acid solution can be prepared by titration. For example, to make a normal sulphuric acid solution:

$$\begin{aligned} H_2 &= 2 \times 1 = 2 \\ S &= 32 \\ O_4 &= 4 \times 16 = 64 \\ &\quad\overline{98} \end{aligned}$$

Valency $= 2$ $\therefore$ $\frac{98}{2} = 49$ grams of H_2SO_4 per liter.

In preparing a normal solution it is easier to make it a little too strong and then dilute to the proper proportions, so about 50 grams of acid should be used to start with.

Ordinary concentrated H_2SO_4 has a specific gravity of about 1.8, and contains about 93 per cent. of the acid, so that to obtain 50 grams of acid, $\frac{50}{.93 \times 1.8}$, or 29.8 c.c., should be used, and to be sure of having the solution of proper strength, at least 30 c.c. is required.

Owing to the evolution of a great deal of heat when

H_2SO_4 and water are combined, it is always best to pour the acid into the water. About 200 c.c. of distilled water should be run into the liter flask and the acid poured into this gradually, cooling down the mixture by allowing a stream of water to run over the outside of the flask.

When the mixture is cold, the flask can be filled to the liter mark. This solution is now an approximate normal solution.

If concentrated acid is not available, a weaker acid may be used and the solution made up by specific gravity, for in the approximate normal solution 30 c.c. of concentrated acid of specific gravity 1.8 have been used, which will weigh 1.8×30, or 54 grams, and 970 c.c. of water weighing 970 grams.

The total weight will be $970 + 54$, or 1,024 grams, and the specific gravity will be 1.024. Hence, using a weaker acid, it may be diluted with distilled water until the specific gravity of the mixture is, say, 1.03.

In each case there will be obtained an approximate normal solution which will contain slightly more H_2SO_4 than is required for the exact normal solution.

This acid solution must now be tested by titrating against the standard solution of Na_2CO_3 previously prepared. For this purpose two burettes, graduated to tenths or hundredths of a c.c., are set up vertically in a stand. One burette, which we will call "A," is filled with the normal alkaline solution and the other, "B," with the approximate normal acid solution.

A small amount of the solution in each burette should be run out in order to fill completely the tip of the burettes, and remove any air bubbles.

The height of the liquid in "A" should now be read carefully and exactly 10 c.c. of the solution drawn off into a glass beaker which has been carefully washed with distilled water.

In order to obtain a larger amount of solution, and thereby giving a better body of color after the indicator has been added, 20 or 30 c.c. of distilled water may be added. Two or three drops of the indicator, methyl orange (as this is not

affected by CO_2) are now added, the solution stirred with a glass rod, and the color becomes yellow.

The height in the liquid in "B" is read, the small cock on the burette opened, and the acid solution allowed to drop slowly into the beaker, the mixture being stirred continually. As the neutralization point is neared, each drop of the acid will give a pink tinge to the solution, which will disappear upon stirring. As soon as the pink color remains, the neutralization is complete, and if exact, one drop of the alkaline solution should turn the mixture yellow.

Now note the reading of "B." The difference between the first and last readings gives the amount of acid required to neutralize the 10 c.c. of normal alkaline solution.

Repeat this titration three or four times, and suppose the results to be as follows:

10 c.c. alkali neutralized by 9.7 c.c. acid.
10 c.c. alkali neutralized by 9.7 c.c. acid.
10 c.c. alkali neutralized by 9.6 c.c. acid.
10 c.c. alkali neutralized by 9.8 c.c. acid.

Average, 10 c.c. alkali neutralized by 9.7 c.c. acid.

The said solution is too strong, as there is sufficient H_2SO_4 in 9.7 c.c. of the solution to neutralize 10 c.c. of the normal alkaline solution, or 970 c.c. contain enough to neutralize 1,000 c.c. of alkaline solution.

Therefore 30 c.c. of distilled water should be put in a liter flask and the flask filled to the liter mark with the acid solution. This should be a very close approximation to a normal acid solution.

A titration should again be made, and if less than 10 c.c. of acid neutralize 10 c.c. of the normal alkaline solution, the acid must be diluted as before and again titrated, this process being continued until 10 c.c. of acid solution exactly neutralize 10 c.c. of alkaline solution.

When the strength of the acid is very nearly, but not exactly normal, instead of attempting to bring it to the precise

normal strength, it may be used as it is, and a correction factor applied. For example, suppose that 9.9 c.c. of acid just neutralize 10 c.c. of alkaline solution, then $\frac{9.9}{10} = \frac{1}{1.01}$, that is, every c.c. of the acid is equal to 1.01 c.c. of an exactly normal acid. Therefore, if the number of c.c. of this acid used in any titration be multiplied by the factor 1.01, the result will be the number of c.c. that would have been required had the acid been exactly normal.

If a fractional normal solution is desired, it may be prepared by first making a normal solution and then diluting it to the proper proportions with distilled water.

For example, a tenth normal acid solution is desired. One hundred c.c. of the normal acid solution are added to 900 c.c. of distilled water, or it may be made directly by using 3 c.c. of the concentrated acid, and diluting with enough distilled water to make a liter. This will be only an approximate one-tenth normal solution, and should be titrated against a tenth normal alkaline solution, if one is at hand, otherwise against a normal alkaline solution, in which case 50 c.c. of the tenth normal acid should just neutralize 5 c.c. of the normal alkaline solution.

Having now both normal acid and alkaline solutions, other normal solutions, as HCL, KOH, etc., may be prepared and titrated against these standards.

The indicator formerly used with the Navy testing outfit was a combination of methyl orange and phenol phthalein. As stated before, methyl orange in a neutral or alkaline solution is yellow, in an acid solution pink; while phenol phthalein in a neutral or acid solution is colorless, but deep red in an alkaline solution. Therefore, if upon the addition of a few drops of this indicator to a solution it becomes yellow, the solution is neutral; if it is now made slightly alkaline, it will turn a deep red, due to the phenol phthalein, or if made slightly acid will turn pink, due to the methyl orange. This indicator then gives a very sharp indication of the point of exact neutralization under ordinary conditions.

Suppose it is desired to determine the percentage of alkalinity of a sample of boiler water. Fifty c.c., or a smaller amount if desired of the water, is measured out into a beaker by means of a burette, and a few drops of the combination indicator added. Upon stirring the solution becomes a deep red, due to the phenol phthalein. The acid solution is now carefully added, stirring the sample continually until the red color disappears. If any carbonates are present in the water, the neutralization is only about half completed, owing to the action of the liberated CO_2 on the phenol phthalein, and more acid must be added until the solution turns a very faint pink, due to the methyl orange.

Suppose that 20 c.c. of tenth normal acid are required to neutralize the 50 c.c. of water, then 40 c.c. would have been required to neutralize 100 c.c. of the sample, or 4 c.c. of a normal acid solution. Therefore the sample was 4 per cent. of a normal alkaline solution in strength.

Owing to the fact that considerable difficulty was experienced in using the double indicator, the phenol phthalein has been left out of the indicator now used in the service, methyl orange alone being used.

The difficulty arose from two causes: first, the action of CO_2 upon the phenol phthalein, mentioned above, and second, "the first color change (due to alkaline water and phenol phthalein) was so marked, the second one so slight (the pink color due to methyl orange and acid) that the inexperienced operator, with the first reaction in mind, unconsciously attempted to make the second one comparable to it, and continued to add acid after the completion of the titration."

To determine the number of grains of chlorine per gallon in boiler water, a solution of silver nitrate of known strength is required, to be used in connection with potassium chromate. The sample to be tested must be neutral before making the test for chlorine.

When silver nitrate is added to a solution containing chlorine, to which the potassium chromate has been added, a white precipitate will be formed, silver chloride, until all the

chlorine present has combined with the silver, when red silver chromate will be formed.

The reactions may be represented—

(1) $AgNO_3 + NaCl = AgCl$ (white precipitate) $+ NaNO_3$.
(2) $2AgNO_3 + MgCl_2 = 2AgCl + Mg(NO_3)_2$.
(3) $K_2CrO_4 + 2AgNO_3 = Ag_2CrO_4$ (red) $+ 2KNO_3$.

This change of color to red indicates the complete precipitation of the chlorine, for the third reaction will not take place until the first two have been completed.

As 50 grains of chlorine per gallon have been established as a limit, it is convenient to make the silver nitrate solution of such strength that it will just precipitate all the chlorine in an equal volume of water containing 50 grains per gallon.

The amount of silver nitrate per liter to make a solution of this strength will be 4.101 grams, for the action of $AgNO_3$ on NaCl is represented by the following equation:

$$AgNO_3 + NaCl = AgCl + NaNO_3.$$

Ag =	107.88
N =	14.01
O_3 =	48.00
	169.89

So that in 169.89 grams of silver nitrate there will be 107.88 grams of silver, or in $\frac{169.89}{107.88}$ grams of silver nitrate there will be one gram of silver.

To form AgCl, 107.88 parts, by weight, of silver combine with 35.46 parts of chlorine, or $\frac{107.88}{35.46}$ parts of silver combine with one part of chlorine.

As 1 gallon = 3.785 liters, 50 grains of chlorine per gallon $= \frac{50}{3.785}$ grains per liter; $\therefore$ to combine with 1 liter of solu-

tion containing $\frac{50}{3.785}$ grains of chlorine, there will be required

$$\frac{50 \times 107.88}{3.785 \times 35.46} \text{ grains of silver, or}$$

$$\frac{50 \times 107.88}{3.785 \times 35.46 \times 15.43} \text{ grams of silver, or}$$

$$\frac{50 \times 107.88 \times 169.89}{3.785 \times 35.46 \times 15.43 \times 107.93} = 4.101 \text{ grams of silver nitrate.}$$

So that a liter of water containing 4.101 grams of silver nitrate will contain just enough silver to precipitate the chlorine in a liter of water which has 50 grains to the gallon.

Therefore, if the sample of water to be tested is 50 c.c., each c.c. of silver nitrate solution added will represent one grain of chlorine per gallon.

THE UNITED STATES NAVAL ENGINEERING EXPERIMENT STATION, ANNAPOLIS, MD.

By Lieutenant Commander E. J. King, U. S. Navy.

The United States Naval Engineering Experiment Station is situated on the Severn River opposite the sea front of the United States Naval Academy, Annapolis, Maryland.

Endeavor will be made to give, within the limits of a paper of this kind, a comprehensive view of the Experiment Station as to its origin, establishment, equipment, accomplishments and aims; to this end the following headings are used:

I. Origin and history.
II. Buildings and grounds.
III. Power plant and shop equipment.
IV. Testing plant and equipment.
V. Personnel.
VI. Activities.
VII. Work accomplished.—General summary.
VIII. Work accomplished.—Some examples.
IX. General remarks.

Acknowledgment of assistance rendered in the production of this paper is due to Rear Admiral W. F. Worthington, U. S. N., former Head of the Experiment Station; to Captain T. W. Kinkaid, U. S. N., present Head of the Experiment Station, and to the members of the technical staff of the Experiment Station.

I.—ORIGIN AND HISTORY.

In 1861 Congress passed an act whose substance required that no patented article connected with marine engines should be purchased or used in connection with any steam

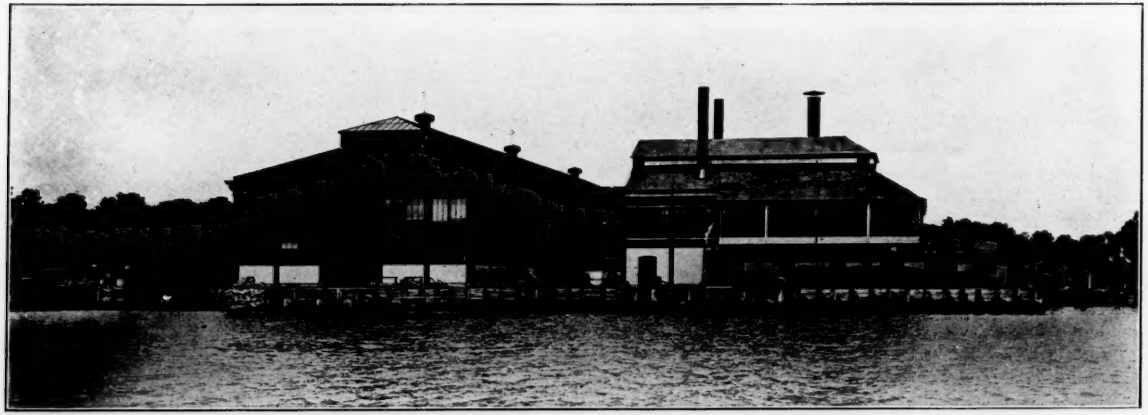


PLATE I.—THE UNITED STATES NAVAL ENGINEERING EXPERIMENT STATION, ANNAPOLIS, MARYLAND.

vessels of war until it had been submitted to a competent board of naval engineers and recommended by them in writing for purchase and use. In complying with the requirements of this act boards were appointed from time to time, when occasion offered, to make such tests as were practicable with such instruments and such improvised facilities as were available. About 1876 Chief Engineer B. F. Isherwood, U. S. N., who had made a reputation as an experimenter and engineer, was appointed senior member of a permanent Experimental Board with headquarters at the New York navy yard. As no funds were appropriated by Congress, the whole cost of testing a patented article fell upon the inventor or producer, and naturally reduced the number of applications; furthermore, the boards were limited in function to the examination of patented articles submitted for consideration and could, therefore, not investigate the merits of apparatus in the process of development nor undertake any systematic inquiry. Later on, as the needs of the Navy for engineer officers increased, the permanent board was dissolved and the practice resumed of appointing boards as occasion required.

As, in the first place, these boards merely examined such patented articles as were submitted for their consideration and had neither authority nor funds to conduct any research work, and, in the second place, the personnel of the boards was rarely twice the same, even the work that was done was accomplished at disadvantage, as they had to improvise apparatus, contrive ways and means, collect data where available and consult such records as could be obtained quickly. This combination of disadvantages may be summed up by saying that there could be no continuity of purpose or of effort in regard to engineering practice in general.

Such research work as was accomplished must be credited to the energy and efforts of those officers who, in addition to their regular duties at sea or on shore, undertook to investigate matters of engineering interest with such meager facilities as could be improvised on the spot. Notable instances of such work are: the screw-propeller investigations of Chief Engi-

neer Isherwood, conducted while he was on duty at the Mare Island navy yard; and the investigation of steam consumption of auxiliary machinery on board ship by Past Assistant Engineer W. W. White, U. S. N., conducted while he was attached to the U. S. S. *Minneapolis.*

When the new Navy was begun it became obvious that the merits of all machinery proposed for use on board ship should be investigated and reported upon in a more authoritative manner, as the number, size and cost of ships became rapidly greater. Disputes were numerous between contractors and the Navy Department as to the installation of certain machinery; the result was that on the one hand some apparatus was placed in ships which never should have been installed, while on the other hand some machinery which would have improved matters was lost to the Navy, for the time being at least.

The striking thing about the engineering arrangements of the Navy was the lack of ways and means: for the systematic investigation of machinery and appliances which were unsatisfactory in their performances, to the end that defects of design, construction or operation might be located and remedied; for the development of improvements that were suggested by officers and men; and, above all, for the careful examination of designs and methods of construction and operation of machinery, considered satisfactory, to discover whether they were capable of improvement in any way, what the principles involved, and whether those principles would apply in any machine already in use or under consideration.

In 1895, Past Assistant Engineer F. C. Bieg, U. S. N., wrote a short article* with a long title which appeared in the JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS, in which was advocated an "Engineer Experimental Station and School" for the dual purposes of experimental research

* JOURNAL AMERICAN SOCIETY NAVAL ENGINEERS, Vol. VII, No. 3, August, 1895—P. A. Engineer F. C. Bieg, U. S. N.—"On the Necessity and Value of Scientific Research in Naval Engineering Matters as Related to the U. S. Navy, and the Necessity of an Engineer Training for the Younger Members of the Engineer Corps of the U. S. Navy."

and engineer post-graduate work. The article was widely discussed by engineers in naval and civil life, the consensus of opinion being strongly in favor of the suggestions advanced.

Engineer-in-Chief G. W. Melville, U. S. N., made recommendations for a number of years to Congress to establish an experimental engineering laboratory, but his efforts were not crowned with success until the war with Spain had made the people realize that there was a Navy, and public interest had been awakened in its expansion and the maintenance of its efficiency, with the final result that the Fifty-seventh Congress passed, on March 3, 1903, an act which contained the following paragraph:

"*Building on Land owned by the Government, Annapolis, Maryland:*

"Bureau of Steam Engineering: or a building to be used as an experiment station and testing laboratory in the department of marine engineering and naval construction (to cost not to exceed two hundred and fifty thousand dollars) two hundred and fifty thousand dollars. For the complete equipment of this building with all the necessary appliances and apparatus as an experiment station and testing laboratory, one hundred and fifty thousand dollars." In all, four hundred thousand dollars.

It is not to be supposed that the Navy Department, in asking for this experiment station, or Congress, in granting the appropriation for it, was introducing any great or radical innovation. Among the arguments advanced for the establishment of an engineering experiment station were the facts that the German Government had established and maintained a testing laboratory near Berlin (Charlottenburg) for some thirty-five years, that other nations had done the same thing, that all large railroad, steamship, and manufacturing companies both in this country and abroad had for years considered their testing laboratories an essential part of their establishments, and that all engineering schools maintained testing laboratories for the better instruction of their students

and for the research work of their professors, instructors and graduate students.

It was found impracticable to place the experiment station building within the limits of the Naval Academy grounds. After some delay in acquiring title to a ten-acre tract of land across the Severn River from the sea front of the Naval Academy, the building was constructed in the years 1906–1908, under the supervision of Rear Admiral (then Captain) W. F. Worthington, U. S. N.

In the meantime the appropriation for equipment of building was made use of in purchasing and installing a set of experimental Parsons turbines in one of the old buildings at the Naval Academy, though little could be done with the makeshift arrangements which necessarily obtained.

The station building was occupied in March, 1908, and the installation of equipment, including removal of that apparatus which had been temporarily installed in an old building at the Naval Academy, was fairly well completed in August, 1908, when the existence of the Station as an essential adjunct to engineering in the Navy may be said to have begun.

II.—BUILDINGS AND GROUNDS.

(See Plates I, II and III.)

The grounds of the Experiment Station contain about ten acres and have a water frontage of about 1,600 feet. Strictly speaking, there is but one building constituting the Experiment Station, though there are, under one continuous roof, three distinct parts—the "main building," the "boiler house," and the "boiler-house extension."

The building is founded on piling and concrete piers and, with its pavements and bulkheads, forms a pier jutting somewhat into the Severn River between two basins, enclosed in bulkheading. A concrete sea wall has been contracted for to surround the building. The east basin is not dredged; the west basin has been dredged and will allow craft drawing four-

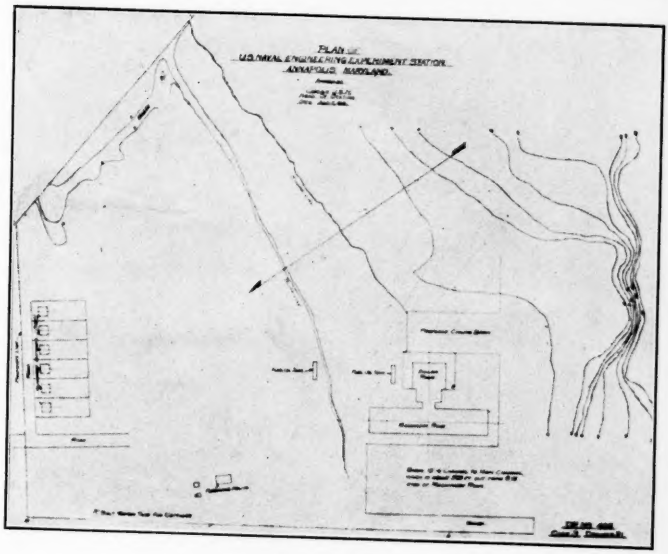


PLATE II.

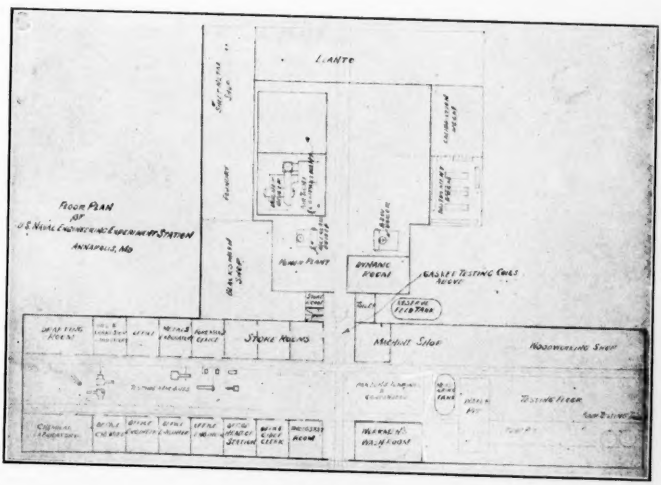


PLATE III.

teen feet to enter from the 30-foot dredged Naval Academy channel, which is about 500 feet distant from the water front of the main building.

The "main building" is three hundred and sixteen feet long, sixty-six feet wide and twenty-nine feet high to the eaves, with brick, concrete and steel lower half and concrete and steel-sash upper half; its long axis is approximately northeast and southwest. From the middle of the eastern side of the "main building" extends an addition called the "boiler house," sixty-six by thirty-four feet; to this addition has recently been added the "boiler-house extension," eighty-six by sixty-six feet, with a twenty-six foot "lean-to" on three sides.

The "main building" may be considered to be in two parts; the northern half contains offices, laboratories, storeroom and toolroom, with testing machines in the central space; the southern half contains the machinery laboratory, machine shop, wood-working shop, etc. A 15-ton crane of full building width traverses the "main building" from end to end.

The "boiler house" contains a Niclausse boiler, a B. and W. boiler, feed heaters, feed pumps, air compressors, condensers, and a dynamo room with a 75-kw. turbo-generator. a small reciprocating generator, balancer, switchboard, etc. This dynamo room is to be extended and enlarged to permit of the installation of an A. C. generator direct-connected to a marine type of Diessel engine. There is a "lean-to" on northern side used for forge shop and storage of bar material.

The "boiler-house extension" contains two air-tight fireroom compartments, in one of which is installed an oil-burning Mosher boiler. The southern "lean-to" is being fitted as an instrument-storage and calibration room. The northern "lean-to" contains the foundry, sheet-metal shop, and gasoline motor testing rig.

An old house located on the ground when purchased by the Government is occupied by the shop foreman. In 1912 there were completed and occupied six small cottages for the firemen, who are also night watchmen.

III.—POWER PLANT AND SHOP EQUIPMENT.

There are three boilers:

1. A marine-type 200-H.P. coal-burning Niclausse boiler designed for pressures up to 300 pounds per square inch, situated in the "boiler room."

2. A marine-type 300-H.P. coal-burning B. and W. boiler designed for pressures up to 500 pounds per square inch, situated in the "boiler room."

3. A marine-type 500-H.P. oil-burning Mosher boiler with large superheater designed for pressures up to 300 pounds per square inch, installed in one of the air-tight fireroom compartments of the "boiler-house extension." The oil-burning system is of the mechanical type and is intended to be capable of burning up to 4,000 pounds of fuel oil per hour with an induced draft of 2½ inches of water, created by an electric motor-driven fan installed in the uptake.

The dynamo room contains a 75-kw., D. C. turbo-generator, 220 volts, 2,400 r.p.m. and a 15-kw., D. C., 110-volt generator, direct-coupled to a reciprocating engine.

Arrangements are underway for the enlargement of the dynamo room, to accommodate the installation of a 75 k.v.a., A. C. generator, direct-coupled to a marine-type Diesel engine, together with a combination A. C.-D. C. switchboard, exciter, motor-generators, etc.

The boiler-room machinery consists of dynamo and auxiliary condensers, feed pumps, feed-water heaters, grease extractor, etc., a small Rand air compressor and two locomotive-type air pumps with combined capacity of about 70 cubic feet of free air per minute.

The machine shop contains lathes, planer, shaper, milling machine, drill presses, pipe-cutting and pipe-threading machines, etc., there being a large amount of pipe fitting necessary in nearly all machinery tests.

The wood-working shop contains lathe, saws, planers, core-box machine, etc. Pattern making in connection with erection of machinery for test is an important shop activity.

The foundry and sheet-metal shop occupy the northern

"lean-to" of the "boiler-house extension." Both of these activities are in constant use in connection with the preparation of tests.

There is a small but well-equipped toolroom and an extensive storeroom, made necessary in order to have on hand the varied supplies of material which are constantly being used.

In the "main building" there are also installed:

A half-ton ice machine of the dense-air type, flushing pumps, motor drive for shafting, evaporators and distillers, etc., mention having already been made of a 15-ton electric crane of building width with travel full length of building.

IV.—TESTING PLANT AND EQUIPMENT.

The testing plant and equipment is extensive and varied in character, an idea of which may be had from the following paragraphs, due notice being taken of the utilization of power-plant apparatus for testing purposes.

The testing-machine (strength of materials) equipment is:

One 300,000-pound tension-compression machine (Olsen).
One 50,000-pound tension-compression machine (Riehle).
One 60,000-pound torsion machine (Olsen).
One fiber-stress endurance machine (White-Souther).
One pendulum impact machine (Olsen).
One continuous impact machine (Cambridge).
One vibratory endurance machine (Olsen).
One ball hardness machine (Brinnell).
Two oil-testing machines (Riehle).

There is also an oil-testing machine of Experiment Station design intended for the comparison of engine and turbine oils; designs are in hand for machines to test steam- and gas-engine cylinder oils.

All small instruments used for testing purposes are to be assembled in one "instrument room," which is in the south "lean-to" of the "boiler-house extension;" here all instruments will be calibrated, cleaned, repaired and stowed ready for use as required.

The photomicrographic laboratory is equipped with two polishing machines, a microscope with vertical illuminator fitted with balopticon and camera, and an electric oven for heat-treatment investigations; a portable photomicrographic apparatus will be added shortly.

The chemical laboratory is fully equipped for analysis of waters, metals, etc., and for the chemical and physical examination of lubricating oils, etc.

The machinery laboratory is outfitted as follows:

There is installed near the center of the "main building" a set of three Parsons experimental turbines of 500 H.P. combined capacity, connected up to condensers of three types—Alberger, Blake, and Contraflo, all of which have wet- and dry-air pumps and are so arranged as to be available for use in connection with other tests.

A large duplex horizontal fire pump discharges into a salt-water tank of 13,000 gallons' capacity, which is used as a supply and measuring tank in tests of condensers, pumps, feed-water heaters, etc. In the west corner of the "main building" are two large cylindrical closed tanks, of 6,000 gallons' capacity each, for use when hot fresh water is to be used in a test.

There are two Navy standard evaporators and a battery of three Navy standard type distillers, together with an evaporator and a distiller of the multicoil type.

There is a large testing platform in eight sections, with a total area of 300 square feet, near which is installed a large and a small venturi meter in parallel, so that either can be used as desired.

Two condensers, each of about 100 square feet of cooling surface, are connected up to two independent exhaust-test lines running through the machinery laboratory, for the purpose of measuring steam consumption of machinery by weighing the condensate.

The portable testing apparatus consists of weighing tanks, scales, venturi meters, prony brakes, water rheostats, water brakes, etc.

There is a 75-H.P. electric dynamometer, constructed for horizontal work, which has recently been adapted for use in a vertical position for the purpose of testing turbo-blowers and other machinery of a vertical type.

There has recently been completed a cylindrical blower-testing chamber made of sheet metal, ten feet in diameter and ten feet high.

Two turbo-blowers of the horizontal type are on hand:

1. A De Laval turbine geared to a sirocco blower with a rated capacity of 15,000 cubic feet of air against a pressure of 5 inches of water.

2. A turbine direct-connected to a propeller fan of rated capacity of 25,000 cubic feet of air against a pressure of 6 inches of water. This blower is installed to discharge into the airtight fireroom compartment containing the oil-burning Mosher boiler.

An idea of the uses to which power-plant apparatus is put for testing purposes may be gained from the following:

The B. and W. boiler is used for coal evaporation and safety-valve capacity tests, for endurance tests of boiler-hand-hole gaskets, boiler tubes, bottom-blow valves, feed-water level regulators and other boiler accessories. The Mosher boiler is fitted for oil evaporation and safety-valve capacity tests.

The feed pumps and condensers of the power plant are made use of for endurance tests of pump valves and packings. Feed pumps, after their performance tests, are usually placed in power-plant service for an endurance test of some months.

In the "boiler house" are placed fittings and apparatus for the endurance testing of ordinary valves, reducing valves, gage glasses, bottom-blow valves, condenser-tube materials and boiler accessories in general.

The bearings of the turbo-generator are made use of for endurance testing of turbine and dynamo oils, while the dense-air ice machine is employed for service tests of ice-machine oils.

On the gallery of the "main building," above the passage-way to the boiler house, are installed two sets of coils for test-

ing packing, one for saturated steam, the other for superheated steam, both being fitted with pressure- and temperature-recording devices.

V.—PERSONNEL.

The personnel of the Experiment Station at present consists of:

The Head of the Station, a naval officer, the present incumbent being Captain T. W. Kinkaid, U. S. Navy.

Two naval officers, who divide between them the management of the plant and the testing of metals, oils, boiler compounds, and miscellaneous tests.

Two mechanical engineers for general machinery tests.

One mechanical engineer who specializes on packings, gasket materials, gage glasses, and boiler fittings and accessories.

One chemist and one assistant chemist for analysis and examination of metals, compounds, oils, fuels, etc.

A draughtsman, chief clerk, stenographer, messenger, etc.

Two engineering observers, assistants to mechanical engineers, who conduct machinery tests.

Laboratory helpers, who assist in test work as observers.

One foreman and one quarterman.

Machinists, pattern maker, molder, sheet-metal worker, blacksmith, boiler maker, firemen, helpers and laborers; in all about sixty in number. Men who have served in the Navy are preferred for employment at the Experiment Station because of their all-around knowledge and familiarity with naval engineering conditions and practice.

The work of the Experiment Station has already increased to such an extent that there is great need for—

A naval officer to devote his entire time to the plant.

A metallographist for photo-micrography and the testing of metals.

An additional mechanical engineer for care, calibration and maintenance of testing equipment and instruments.

Additional engineering observers as assistants to mechanical engineers who conduct general machinery tests.

VI.—ACTIVITIES.

The Experiment Station is under the control of the Bureau of Steam Engineering of the Navy Department by whom all test work is authorized, the costs being charged to the proper appropriation or against a "special deposit" made by the exhibitor of the apparatus or material to be investigated. As the Experiment Station is situated near the Naval Academy, the Superintendent of the Naval Academy exercises the functions of the commandant of a naval station with regard to the Experiment Station.

The activities of the Experiment Station are more numerous and more varied than the title "Experiment Station" would seem to indicate, and may be grouped under five general heads, namely:

1. Testing
2. Research } covering all experimental work.
3. Instruction
4. Increase and improvement of equipment.
5. Repair and maintenance.

It is difficult to distinguish clearly in some cases between testing and research work; all investigations are given a "test number" by which they are handled while in progress and referred to in reports and records.

"Testing" may be considered as undertaken for the following purposes:

(*a*) Examination for conformity with specifications.

(*b*) Examination for the framing of specifications.

(*c*) Performance and endurance of machinery.

(*d*) Performance and endurance of apparatus and accessories.

(*e*) Performance and composition of materials.

Any given "test" may require that more than one of the above-mentioned lines of investigation be undertaken.

"Research" may be considered as applying where—

(*a*) Existing data is not systematic or sufficient.

(*b*) A new combination of mechanical principles is desired or proposed for a special purpose.

(*c*) A new combination of physical principles is desired or proposed for a special purpose.

(*d*) A new combination of mechanical and physical principles is desired or proposed for a special purpose.

(*e*) A new material or compound is to be developed for a special purpose.

"Instruction" at the Experiment Station has taken the form of—

(*a*) For midshipmen: Inspection of testing plant and equipment; demonstrations of such tests as may be underway or specially arranged; demonstrations of test apparatus and machinery in operation.

(*b*) For student officers of the post-graduate department of the Naval Academy: Practical work in engineering chemistry; photomicrography and tests of strength of materials; testing of boiler-feed water and prevention of boiler corrosion; testing of packings, gage-glasses, gasket material and boiler accessories; assistants to mechanical engineers in charge of machinery tests; in erecting machinery for test, calibrating testing apparatus and instruments, taking test data, computing results and framing conclusions. Some of this work is undertaken while pursuing scholastic work, but the bulk of it is accomplished during a period of three or four months during which the student officers give their whole time to the Experiment Station, endeavor being made to enable them to gain a working knowledge of all the test and research work underway.

(*c*) Instruction has been given in photomicrography principles and practice to assistants to inspectors of engineering materials and to the officer in charge of the central tool plant at the Navy Yard, Philadelphia.

The Head of the Experiment Station is ex-officio a member of the Council of the post-graduate department of the U. S. Naval Academy.

"Increase and improvement of equipment" involves much time and study in the examination of testing instruments and apparatus on the market and in the evolution, development

and improvement of apparatus to meet the special needs of the Experiment Station, this latter being especially important because of the need for apparatus which will as nearly as possible duplicate conditions on board ship in the Navy.

"Repair and maintenance" applies not only to the Experiment Station buildings, plant and equipment, but also to—

(*a*) Hydroaeroplanes and their accessories belonging to the Navy Aviation Camp, which is situated in the immediate vicinity of the Experiment Station and is under its administrative control.

(*b*) Annapolis Reserve Torpedo Division, which is berthed in the Experiment Station West Basin and utilizes the facilities of the Station for upkeep. Boats of this division have been used for radio tests and experiments for direction, distance, apparatus, etc.

Mention should be made of work done in which the Bureau of Steam Engineering is not directly interested; the more important "tests" of this class are—

(*a*) Performance tests of safety valves for the Isthmian Canal Commission for acceptance.

(*b*) Auxiliary emergency radio outfits for Bureau of Commerce and Labor.

(*c*) Examination of materials for Bureau of Ordnance.

(*d*) Examination of galvanizing processes for Bureau of Construction and Repair.

(*e*) Performance tests of locomotive safety valves for the Interstate Commerce Commission for capacity rating.

(*f*) Performance tests of aeroplane motors for Signal Corps, U. S. Army, for acceptance. (See Plate VIII.)

VII.—WORK ACCOMPLISHED—GENERAL SUMMARY.

As already stated, the Experiment Station took its place as a working part of the Bureau of Steam Engineering in August, 1908; it has, therefore, been in operation for about five years. Naturally, the first two or three years of its existence are not conspicuous for the amount of work done, much time

being consumed in settling down, and in readjustments and devolopments, but at this time the Experiment Station may be said to be fairly underway. Probably the only external measure of the amount of work may be expressed by stating that to date some three hundred and sixty "tests" have been undertaken, but it must be remembered that some of these tests involve an amount of time and labor entirely disproportionate to that consumed in some other "tests."

It is impracticable to cite the "tests" that have been undertaken, and it is rather a difficult matter to group tests which cover so wide a field, so that it must be borne in mind that what is given here is merely an attempt at a comprehensive summary, in which the character of the work cannot be more than indicated, and that the items enumerated in the groups in nearly all cases represent several "tests." The general headings are treated in separate paragraphs.

"Machinery tests," including turbines, blowers, turbo-blowers, rotary engines, rotary pumps, simplex reciprocating boiler-feed pumps, turbine-driven centrifugal boiler-feed pumps, air-refrigerating machines, etc.

"Heat-transmission apparatus," including condensers, evaporators, distillers, feed-water heaters, oil heaters, air heaters, and research work in heat transmission.

"Boiler fittings and accessories," including gage glasses, safety valves, water-level indicators, boiler-tube cleaners, soot blowers, gage-glass frames, try cocks, bottom-blow valves, pressure gages, pressure recorders, oil burners, baffles, etc.

"Pump and engine fittings and accessories," including pump-valve gear, feed-water regulators, pump governors, pressure regulators, pump valves and valve seats, graphite lubricator, oil drips, grease caps, engine direction indicators, revolution counters, speed indicators, tachometers, carburetors, spark coils, gasoline shut-off, etc.

"Valves and piping fittings and accessories," including ordinary valves, reducing valves, steam traps, flange joint, armored steam hose, pipe unions, thread-tight compound, pipe

wrenches, insulation of steam piping through watertight bulkheads, heat insulating materials, etc.

"Fuels," including briquettes; coal stored under water, under cover, and in the open; coal from old *Maine;* smoke preventive for coal, etc.

"Lubricants," including oil deposits, used oils, greases; ice machine, turbine, engine, dynamo, forced lubrication, steam cylinder (saturated and superheated steam), gas engine, and gas-engine cylinder oils; graphite, graphite mixtures, etc.

"Packings and gasket materials," including sheet packing for saturated and superheated steam, rod packing, piston packing, gage-glass grommets, gas-engine cylinder packing, slip-joint packing, plastic packing, metallic packing, boiler hand-hole and man-hole gaskets, etc. This is the most numerous class of tests, there being some thirty "tests" on record, one of which embraces seventy-five different kinds of packing, while another has to do with forty-five kinds.

"Strength and composition of metals"—including chemical analysis, strength and endurance, and structure as shown by photomicrography—bearing metals, boiler-tube materials, valve materials for superheated steam, brasses and bronzes, cast irons and steels, alloys of steel with vanadium, chromium, nickel, etc.; monel metal, vanadium, condenser-tube materials; defective boiler headers, drums, nipples, furnaces and tubes; defective crankshaft and bolt material, fuse stock, galvanizing fluxes, gun-jacket material, etc. Photomicrographic work has been underway for about two years; it is now well developed and occupies an important place in the investigation of metals.

"Chemical analyses," including, in addition to "metals" as stated above, boiler compounds, boiler waters; boiler deposits, scales, residues; turbine deposits and scales; gas-engine muffler deposits, refrigerating-brine solutes, etc. Mention may also be made here of tests of gas-analysis apparatus and coal calorimeters, etc.

"Miscellaneous tests" include gasolene drums, carbon remover, thermometers, ball and roller bearings, expansion-screw sleeve, lock nut, lock washer, paraffin illuminants,

whistles operated by air or steam, cotton tape, stuffing boxes, flexible coupling, temperature recorders, etc.

"Miscellaneous investigations" include inquiry into water circulation in B. and W. boilers; development of machines for testing engine oils, steam-cylinder oils and gas-engine cylinder oils; radio tests for direction, distance and equipment; corrosion of boiler-tube and other materials; heat transmission between steam-water and steam-air through metals; effects on action of condensers of air leakage, temperature of inlet water, and quantity of circulating water; radio equipment for aeroplanes; auxiliary emergency radio outfits; effects of moisture on economy of small steam turbines; aeroplane construction and equipment; rifled condenser tubing; effect of retarders in feed-water heater tubes; zinc as a protective agent in boilers and condensers; steam whistles for tactical purposes; variation of specific heats of oils and brines with temperature; and many others.

VIII.—WORK ACCOMPLISHED—SOME EXAMPLES.

In order that the work of the Experiment Station may be better appreciated, brief mention will be made of some of the more prominent work in the several classes of tests:

(*a*) Gage glasses have been thoroughly investigated, with the result that a type of gage glass, employing mica to insulate the glass from the action of steam, has been found, which will give good service with a minimum of breakdown and attention.

(*b*) The tests of packing have been long and tedious, but the work done has contributed largely to the reduction of the number of items on the schedules for packing contracts to a half-dozen classes of packing, the several bids being considered in connection with the behavior of the corresponding packings in tests at the Experiment Station. The prices of packing have been materially reduced since Experiment Station testing has been underway.

(*c*) Lubricating oils are undergoing investigation with a view to developing a method of examination before use which

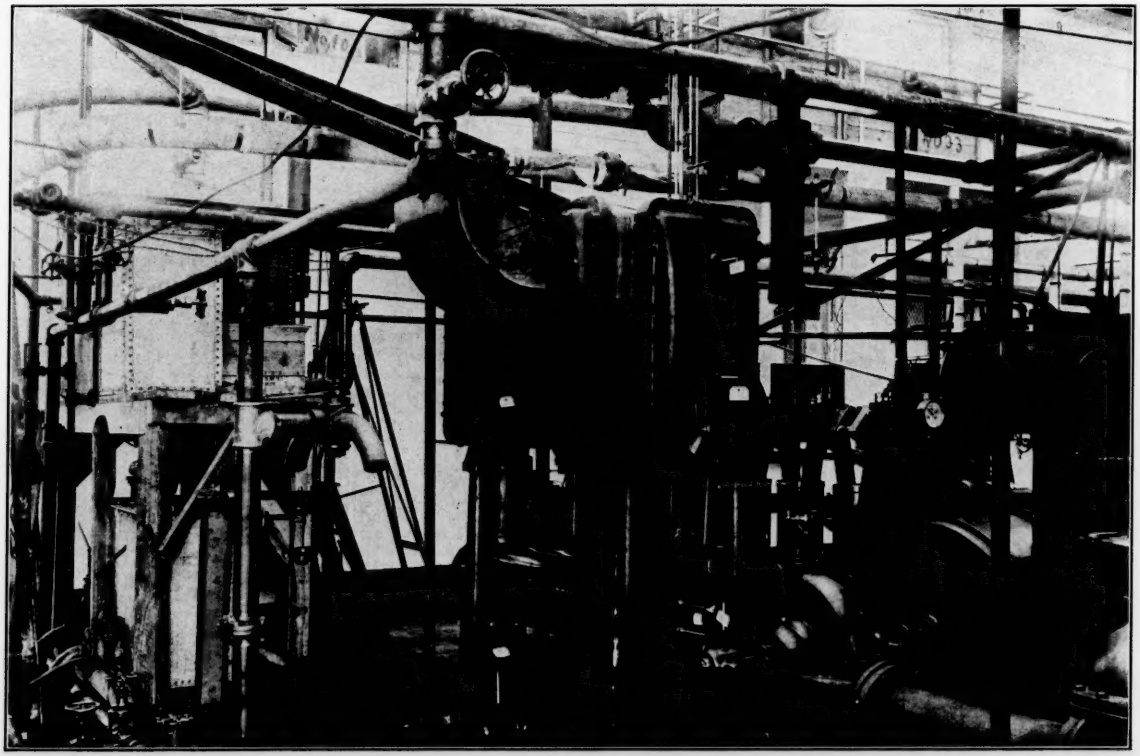


PLATE IV.—CONTRAFLO CONDENSER EQUIPPED FOR INVESTIGATION.

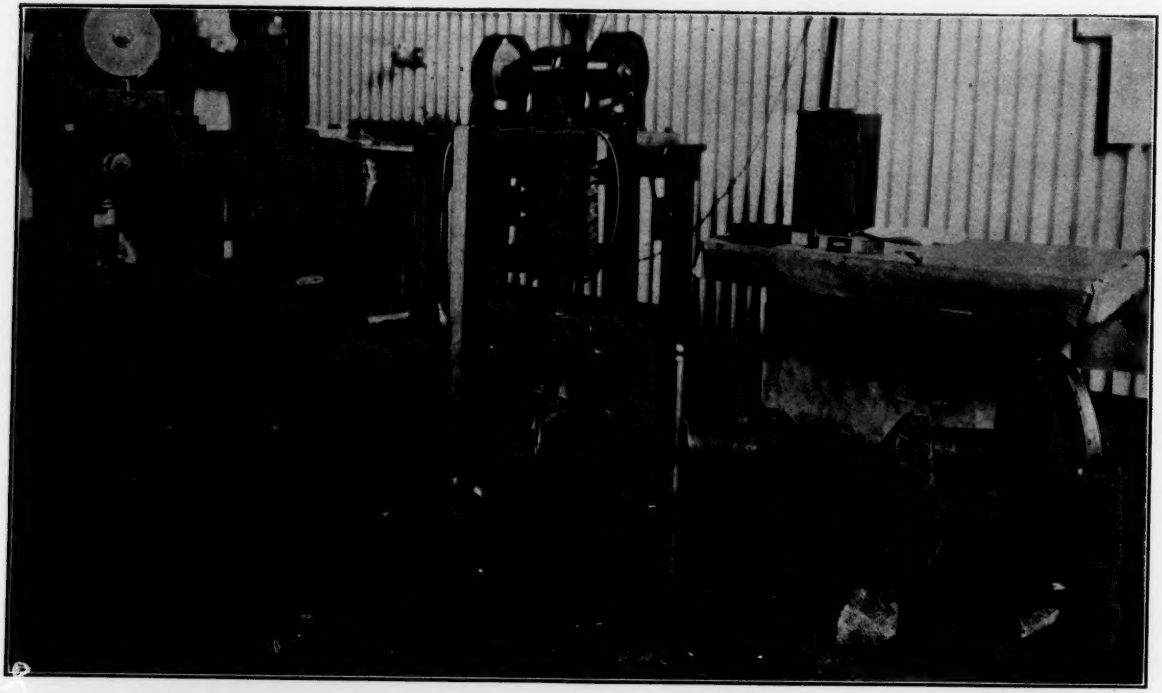


PLATE V.—PHOTOMICROGRAPHIC APPARATUS MOUNTED ON CRANKSHAFT OF SUBMARINE FOR INVESTIGATION.

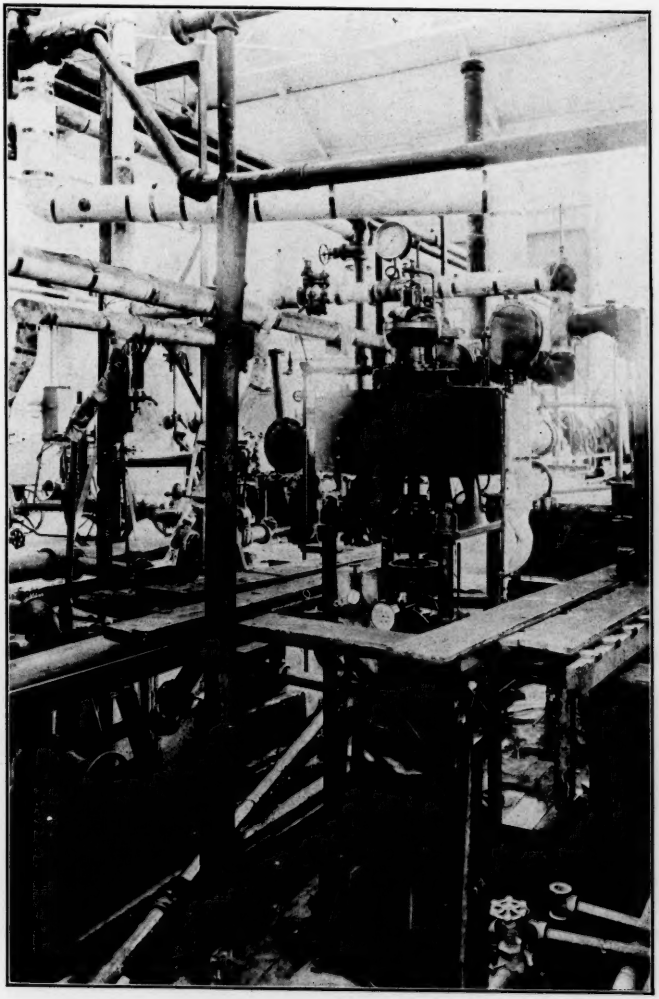


PLATE VI.—TURBINE-DRIVEN CENTRIFUGAL BOILER-FEED PUMP ARRANGED FOR TEST.

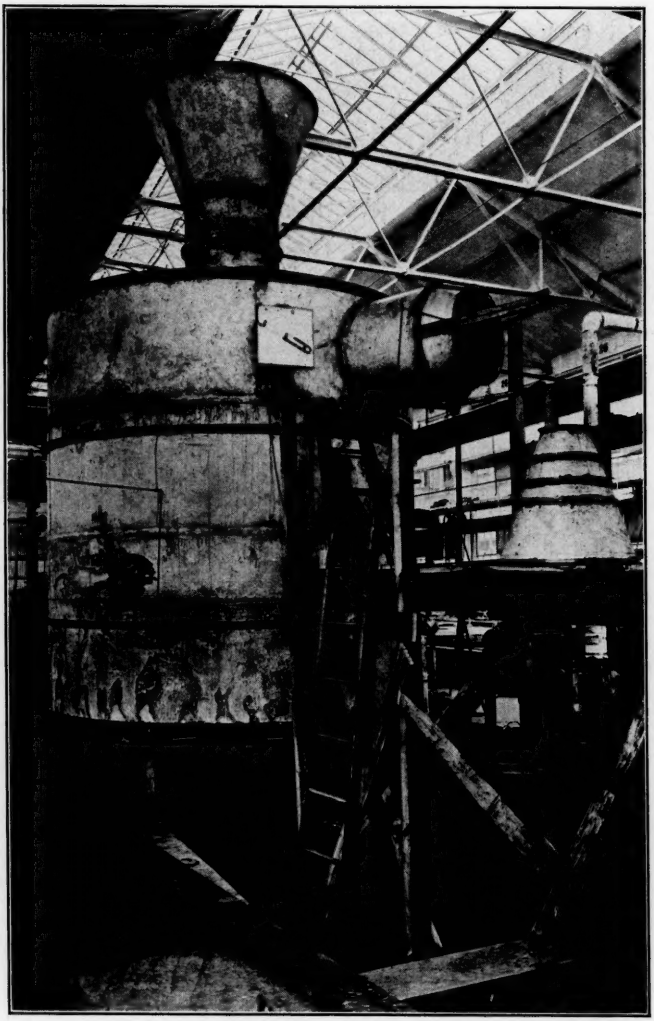


PLATE VII.—BLOWER TEST CHAMBER MOUNTED TO TEST TURBO-BLOWER FOR DESTROYER.

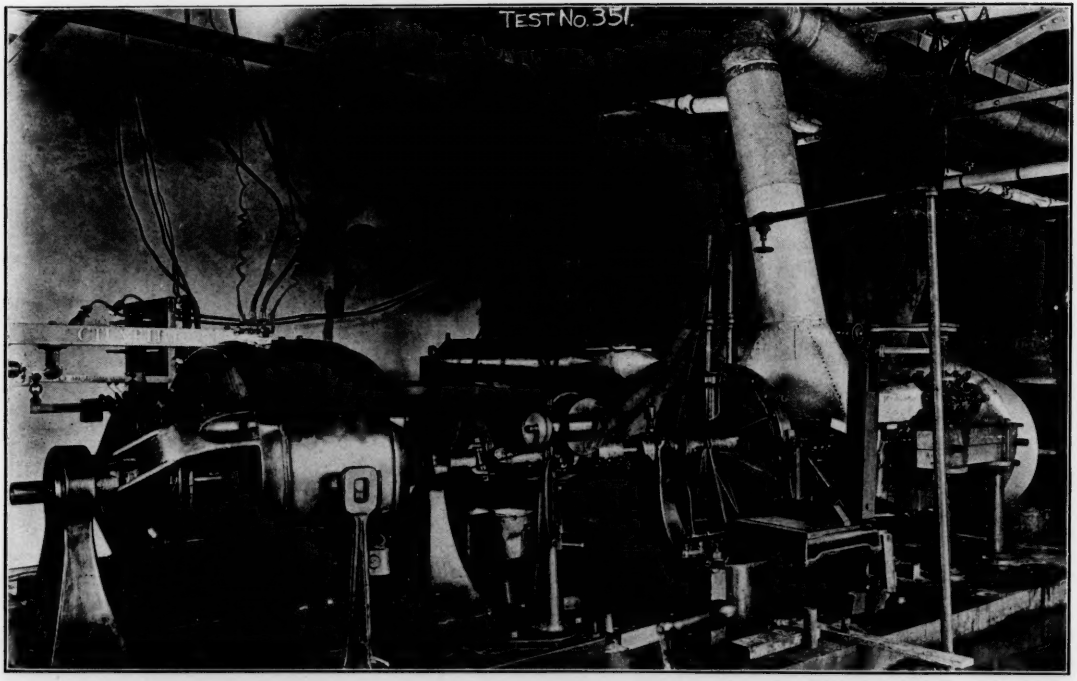


PLATE VIII.—AEROPLANE MOTOR ERECTED FOR TEST.

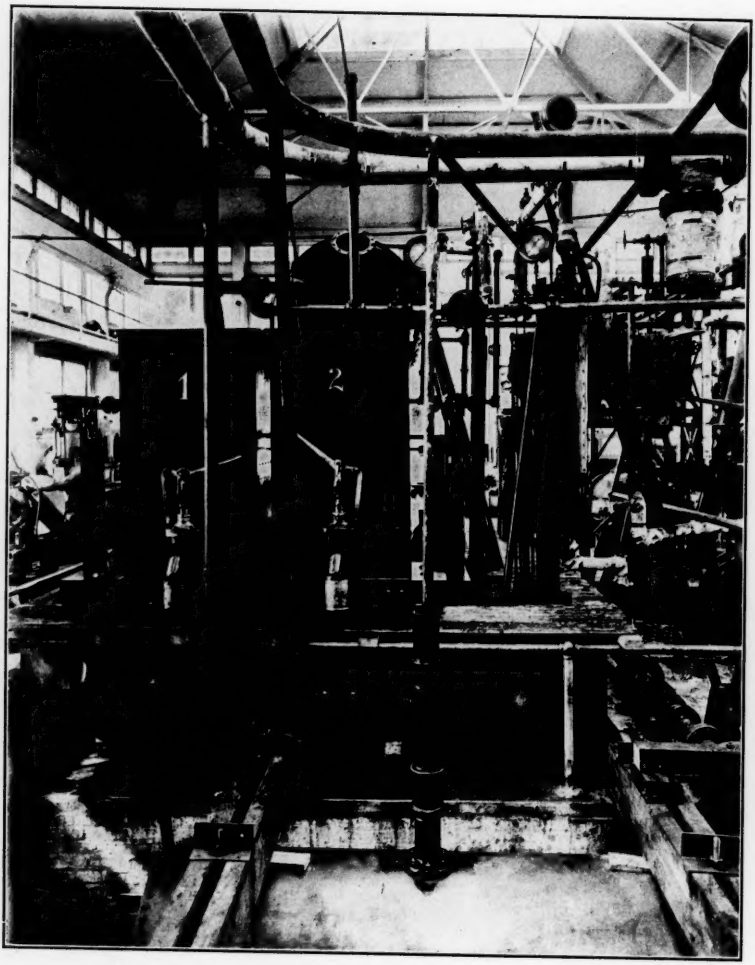


PLATE IX.—WATER AND OIL METER ARRANGED FOR TEST.

will indicate performance in service. Although little is known in this field, developments are already at hand which indicate probable success in this endeavor, so that lubricating oils may be placed in the same relative status with packings, as mentioned above. These investigations have led to the development and construction of an oil-testing machine of Experiment Station design (for the examination of engine and turbine oils) which is very promising in its results, though not yet fully demonstrated. There are now underway designs for oil-testing machines for the examination of steam-cylinder and gas-engine cylinder oils.

(*d*) Corrosion of boiler materials has received a good deal of attention, both as to the materials themselves and as to the treatment of boiler waters, with the result that there has been developed a boiler compound which when properly used will prevent corrosion. The Experiment Station also assisted in the development of a boiler-water testing outfit for use on board ship in connection with prevention of boiler corrosion.

(*e*) Photomicrography has been taken up in the last two years and has progressed markedly, so that reliable information may now be had as to the probable causes of failures of used metals (see Plate V) and as to the probable performance of metals proposed for use, by examination of its grain structure and investigation as to its heat treatment.

(*f*) Tests have been made, and will continue, as to the relative evaporative efficiencies of coal stored under salt water, under cover, and in the open. Coal from the old U. S. S. *Maine* was tested for evaporative efficiency after having been submerged in the water of Havana harbor for fourteen years.

(*g*) Apparatus involving heat transmission forms a considerable part of the testing work. While there is lots of data on heat transmission it is largely unrelated; there has been constructed at the Experiment Station an apparatus for the investigation of heat transmission as between steam-water and steam-air, by means of which it is hoped to secure correlated data and to develop fundamental principles for the design and construction of all heat-transmission apparatus

made or offered for use in the naval service. Along this same line some work has been done with different types of condensers, and there are in hand investigations as to the effect of air leakage, temperature of inlet water, and quantity of circulating water on condenser efficiency (see Plate IV).

(*h*) Boiler-feed pumps of the simplex reciprocating type have been tested in a variety of makes, with the result that no pumps for use on board ship are allowed to be installed unless long known as satisfactory in service or reported as having passed a satisfactory performance and endurance test at the Experiment Station. Among the boiler-feed pumps tested there has been one which was of the turbine-driven, centrifugal type (see Plate VI).

(*i*) Turbo-blowers for installation in torpedo-boat destroyers are being investigated at the Experiment Station both for efficiency of the blower and for efficiency of the turbine. This work has necessitated the construction of a special blower test-chamber (see Plate VII) and the adaption of a horizontal electric dynamometer for use in the vertical position.

(*j*) Tests to determine the accuracy of several water- and oil-metering devices for ship service, and the effect of continuous service on these devices (see Plate IX).

(*k*) Investigation of several types of fuel-oil burners to discover effect of pressure and temperature of oil on the quantity discharged.

(*l*) Reducing valves, bottom-blow valves, pump valves, and ordinary valves have been subjected to thorough performance and endurance tests to the end that only those which combine simplicity of design, sureness of operation and length of service may be supplied for use in the Navy.

(*m*) Safety valves have been and are being tested; the work done has had to do with capacity rating, lift of valve, design of springs, valve and valve seat, etc., and has resulted in the modification of specifications in several particulars, the nature of which had not been clearly understood or appreciated.

IX.—GENERAL REMARKS.

All "tests" are conducted from a "service" point of view and under conditions as nearly approaching conditions on board ship as the facilities of the Experiment Station will permit, special effort being made to conduct endurance tests where practicable.

Reports are written so as to embrace the following general headings:

1. Origin of test—authority for test.
2. Subject of test—description of material or apparatus tested, including history, if any.
3. Purpose of test—the specific lines of investigation to be followed.
4. Test apparatus—description of test apparatus and arrangements.
5. Manner of conducting test—observations taken, conditions maintained, etc.
6. Results of test—test data.
7. Discussion of results.
8. Conclusions.
9. Recommendations.
10. Plates, charts and curves.

Though attention has been called to the fact that the Experiment Station has so far had little time for original research work, mention should be made of the general practice obtaining wherein all "tests" are investigations into the merits of the subject of test; as indicated in the preceding paragraph, reports generally contain discussion, conclusions and recommendations which are worked out with a view to the probable improvement of the subject of test; this is done especially where the subject of test is reported upon as unsatisfactory as a whole or in part.

Reports of "tests" are transmitted in triplicate to the Bureau of Steam Engineering, which forwards a copy of the report to the exhibitor, if there be one. All exhibitors are prohibited from using these reports for advertising purposes

though they may, of course, make use of the report as they see fit for the alteration and improvement of their product.

The results of the work done at the Experiment Station have a very limited circulation—some of them are made known to naval officers by the Bureau of Steam Engineering; some of the "tests" appear in the JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS—but there is no means of making known to the country at large the results of such investigations as might be of general interest and information and are not of such nature as to be considered confidential. Apparently some means should be had for this purpose, probably corresponding in character to the bulletins issued by the Bureau of Mines of the Department of the Interior and other Government bureaus and by State and college experiment stations all over the country.

The field of naval engineering research is wide in extent and its problems are varied in character; it will be seen from this paper that many of the problems have not yet been touched by the Experiment Station, but it is certain that a beginning has been made, and it is to be expected that the Experiment Station will continue to grow in importance and increase in value, to the Navy in particular and to the engineering world in general. The Experiment Station has been established and is now fairly in a position to demonstrate its continuing usefulness; the work it is intended to do will never be completed; there will always be progress; and it is the work of the Experiment Station to assist in determining what is progress—and what is not.

DESCRIPTION OF NURNBERG TWO-CYCLE 450-B.H.P. HEAVY-OIL ENGINES.*

By Lieutenant Commander Louis Shank, U. S. Navy, Member.

PROBLEMS CONFRONTING THE HEAVY-OIL ENGINEER.

Before beginning the description it should be pointed out that the heavy-oil engine is not the simple machine that many writers and exploiters of the engine have made it out to be. The general impression prevails that all that is necessary to do to operate this engine is to turn a wheel, and the operator then can sit down and read a newspaper, the engine taking care of itself. This sort of misinformation has done incalculable damage to the heavy-oil engine industry, and probably has been the cause of the very slow development of the engine in the United States. Lower-power stationary engines do run exceedingly well with very little care, but the higher-speed engine and the marine type require much more care than the slow-running stationary type. As a matter of fact there are as many complications in the Diesel engine as in the steam engine, and if one takes into consideration the relative newness of the heavy-oil engine, as compared with the steam engine, the complications are much more numerous. For instance, in the 450-H.P. engine to be described there are about 2,500 different kinds of parts.

One of the first things an engineer must do when taking up the heavy-oil engine is to drop his steam-engine prejudices. In so many ways the method of operating is so different from the method of operating a steam engine, that to a steam en-

* As built by the New London Ship and Engine Co., Groton, Conn.

gineer it would appear that nothing but disaster could follow the use of such methods. For instance, the steam-engine cylinders are jacketed with steam, while the oil-engine cylinders are jacketed with water; the steam engine requires slow and uniform warming up, while the oil engine is started up without any preliminary preparation. Therefore, when the study of the oil engine is taken up, a fresh start should be made, and the subject approached with an open mind, unhampered by steam-engine prejudices. There is too much of a tendency, when trying out something new and something goes wrong, to say that the new thing is no good, and too little of the opposite tendency, of making the new thing good by correcting its faults. And this is exactly the problem of the heavy-oil engine—to correct minor faults.

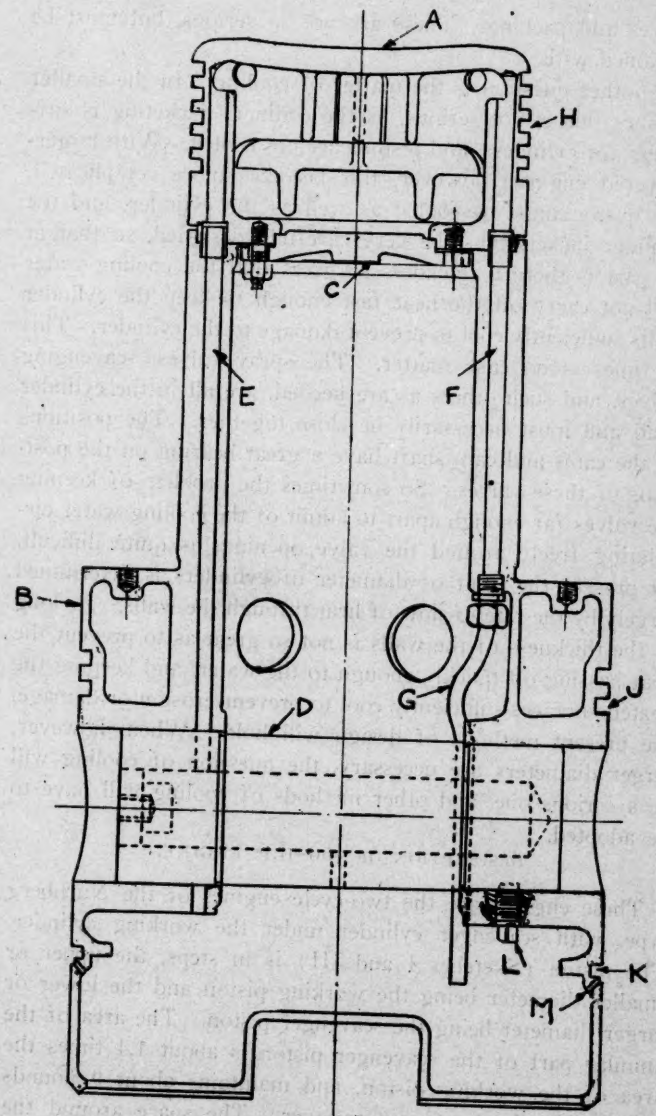
It should be remembered that even with the great strides made in the last five years the heavy-oil engine is still an infant, and much remains to be done before it can approach the degree of development of the steam engine. Much has already been done, and the results shown are remarkable, but a great deal more will be done, for there are many problems yet to be solved. One of the interesting side questions that have arisen is the one of castings. The heavy-oil engine is the despair of iron-foundry men. So far, in the construction of these engines for submarines, 90 per cent. of the cylinders cast have been rejected at some time during the process of manufacture. This trouble has been so great that the manufacturers have put an engineer on the work of solving this question. It had to be approached from a scientific standpoint. The questions of gates, risers, chills, cores, etc., were thoroughly studied, and many experiments made. It is believed that the development has reached the point where 50 per cent. of the cylinders will pass all the tests and trials. This merely shows how the development of the oil engine is affecting other branches of engineering, and indicates the way the development is going, for, when the material question is solved, most of the heavy-oil engine troubles will be solved. Material troubles enter into other parts of the engine, as, for instance,

valves and packing. These are not so serious, but must be reckoned with.

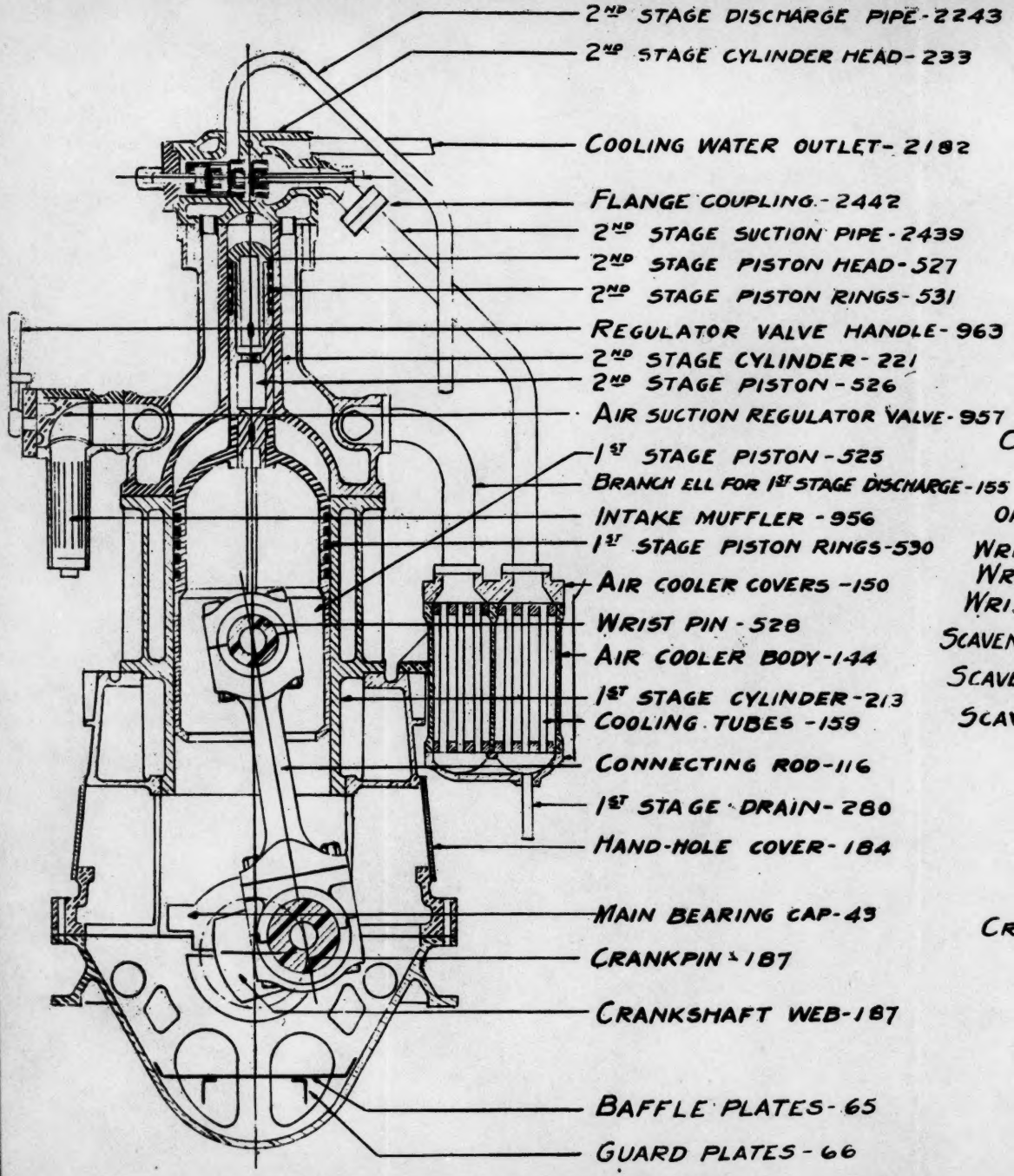
Another question is the matter of cooling. In the smaller engines this is not serious, as the ordinary jacketing is sufficient for cylinders, and pistons are not cooled. With larger-powered engines, however, this becomes more complicated. The piston must be cooled as well as the cylinder, and the cylinder jackets must be very carefully designed, so that at no part is there a thickness so great that the cooling water will not carry off the heat fast enough to keep the cylinder walls sufficiently cool to prevent damage to the cylinder. This at times is no easy matter. The spray valves, scavenging valves, and such others as are needed, are all in the cylinder head and must necessarily be close together. The positions of the cams and cam shaft have a great bearing on the positions of these valves. So sometimes the problem of keeping the valves far enough apart to admit of the cooling water circulating freely around the valve openings is quite difficult. At present the limit of diameter of cylinders is determined largely by the rate of flow of heat through the walls. As long as the thickness of the walls is not so great as to prevent the heat passing off quickly enough to the water, and keeping the heated surfaces sufficiently cool to prevent erosion or damage, the present methods of design will hold. When, however, larger diameters are necessary, the question of cooling will be a serious one, and other methods of cooling will have to be adopted.

DESCRIPTION OF 450-H.P. ENGINE.

These engines are the two-cycle engines of the Nurnberg type, with scavenger cylinder under the working cylinder. The piston (Sketches I and III) is in steps, the upper or smaller diameter being the working piston and the lower or larger diameter being the scavenger piston. The area of the annular part of the scavenger piston is about 1.4 times the area of the working piston, and maintains about 9 pounds pressure in the scavenger receiver. The space around the scavenger cylinder in the housing is used as a scavenger re-



SKETCH I.


2ND STAGE DISCHARGE PIPE - 2243
2ND STAGE CYLINDER HEAD - 233
COOLING WATER OUTLET - 2182
FLANGE COUPLING - 2442
2ND STAGE SUCTION PIPE - 2439
2ND STAGE PISTON HEAD - 527
2ND STAGE PISTON RINGS - 531
REGULATOR VALVE HANDLE - 963
2ND STAGE CYLINDER - 221
2ND STAGE PISTON - 526
AIR SUCTION REGULATOR VALVE - 957
1ST STAGE PISTON - 525
BRANCH ELL FOR 1ST STAGE DISCHARGE - 155
INTAKE MUFFLER - 956
1ST STAGE PISTON RINGS - 530
AIR COOLER COVERS - 150
WRIST PIN - 528
AIR COOLER BODY - 144
1ST STAGE CYLINDER - 213
COOLING TUBES - 159
CONNECTING ROD - 116
1ST STAGE DRAIN - 280
HAND-HOLE COVER - 184
MAIN BEARING CAP - 43
CRANKPIN - 187
CRANKSHAFT WEB - 187
BAFFLE PLATES - 65
GUARD PLATES - 66

SKETCH II.—SECTION THROUGH AIR COMPRESSOR.

-2243

233

182

439

527

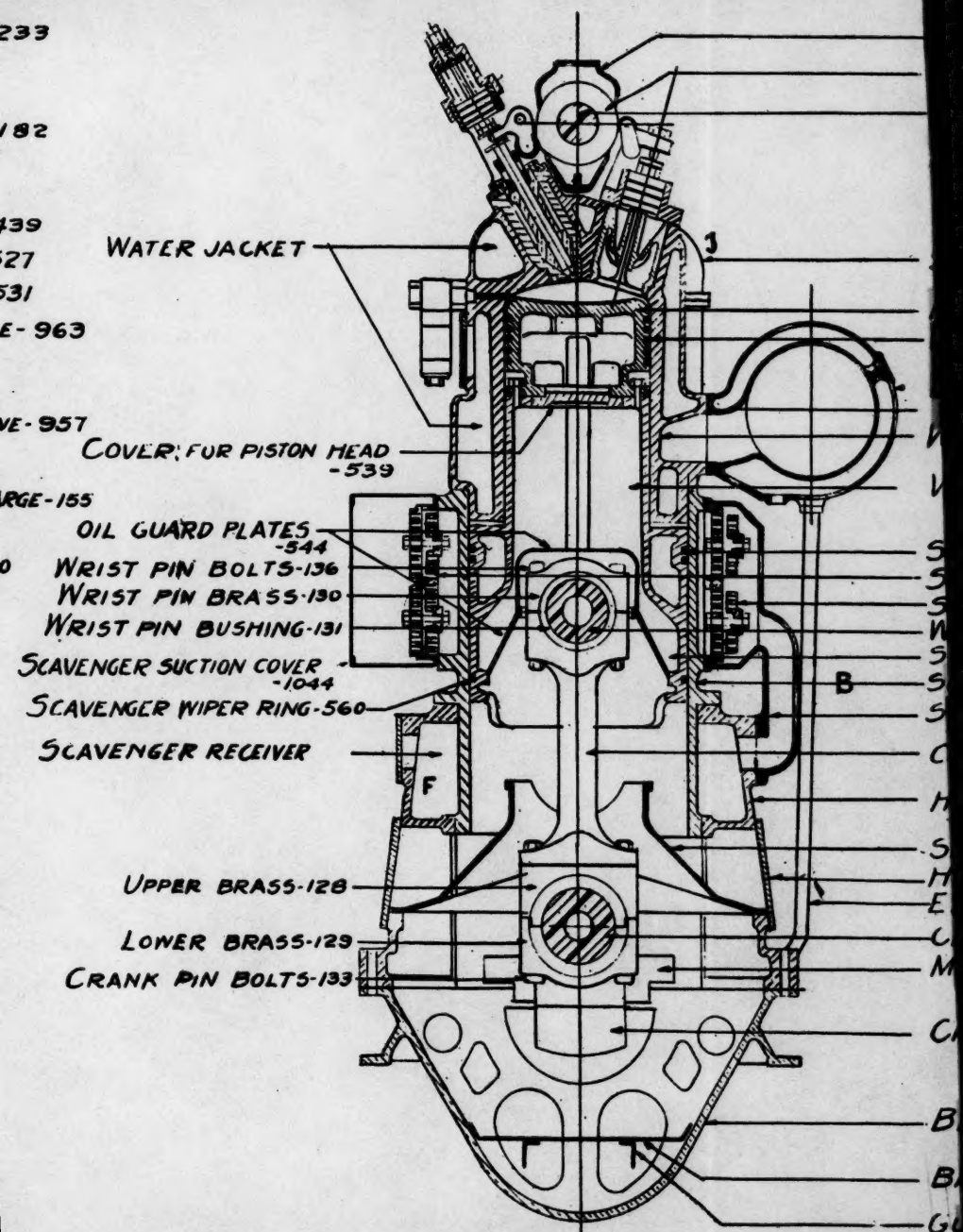
531

E-963

VE-957

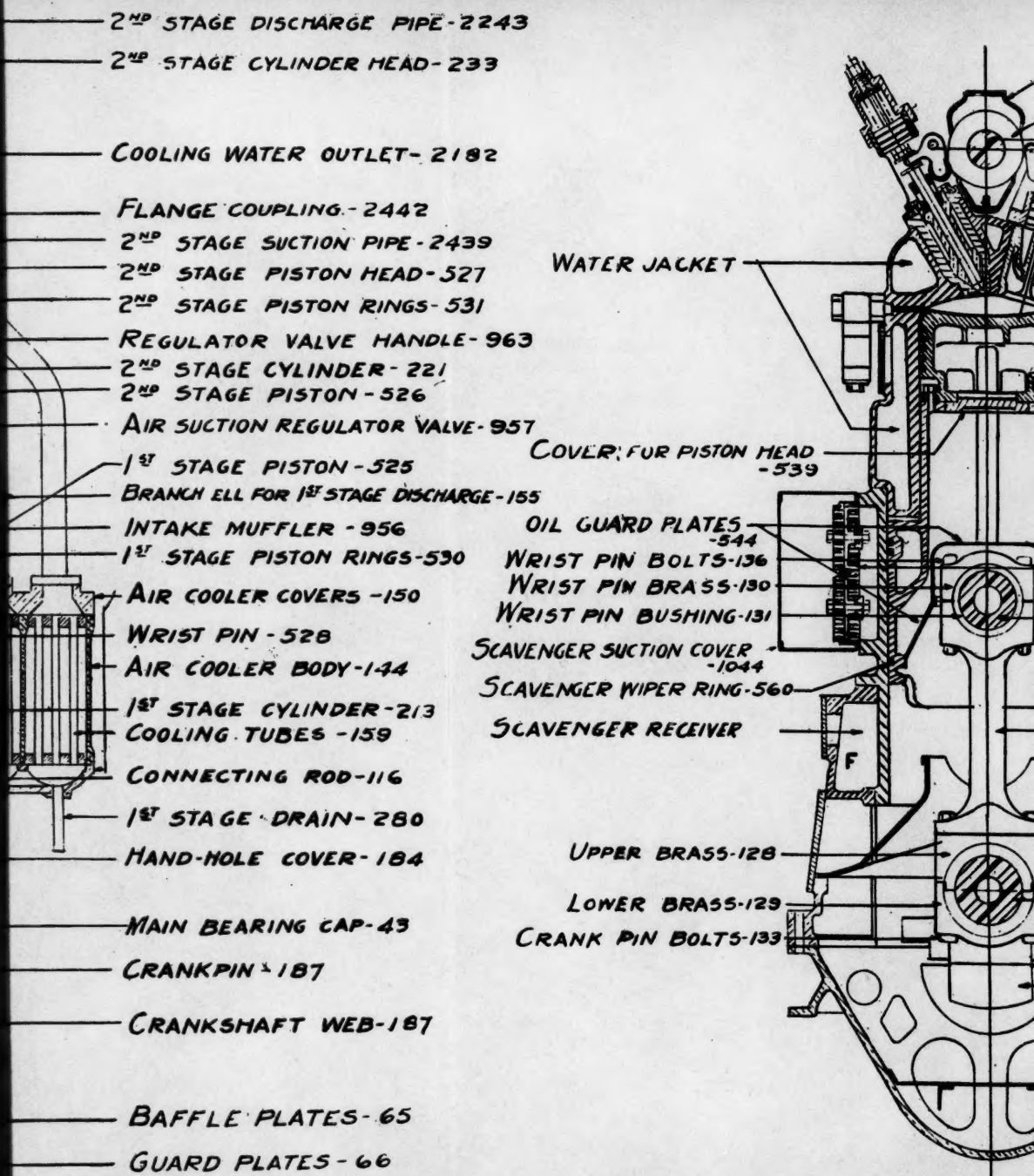
RGE-155

0



SKETCH III.—SECTION THROUGH WORKING CYL

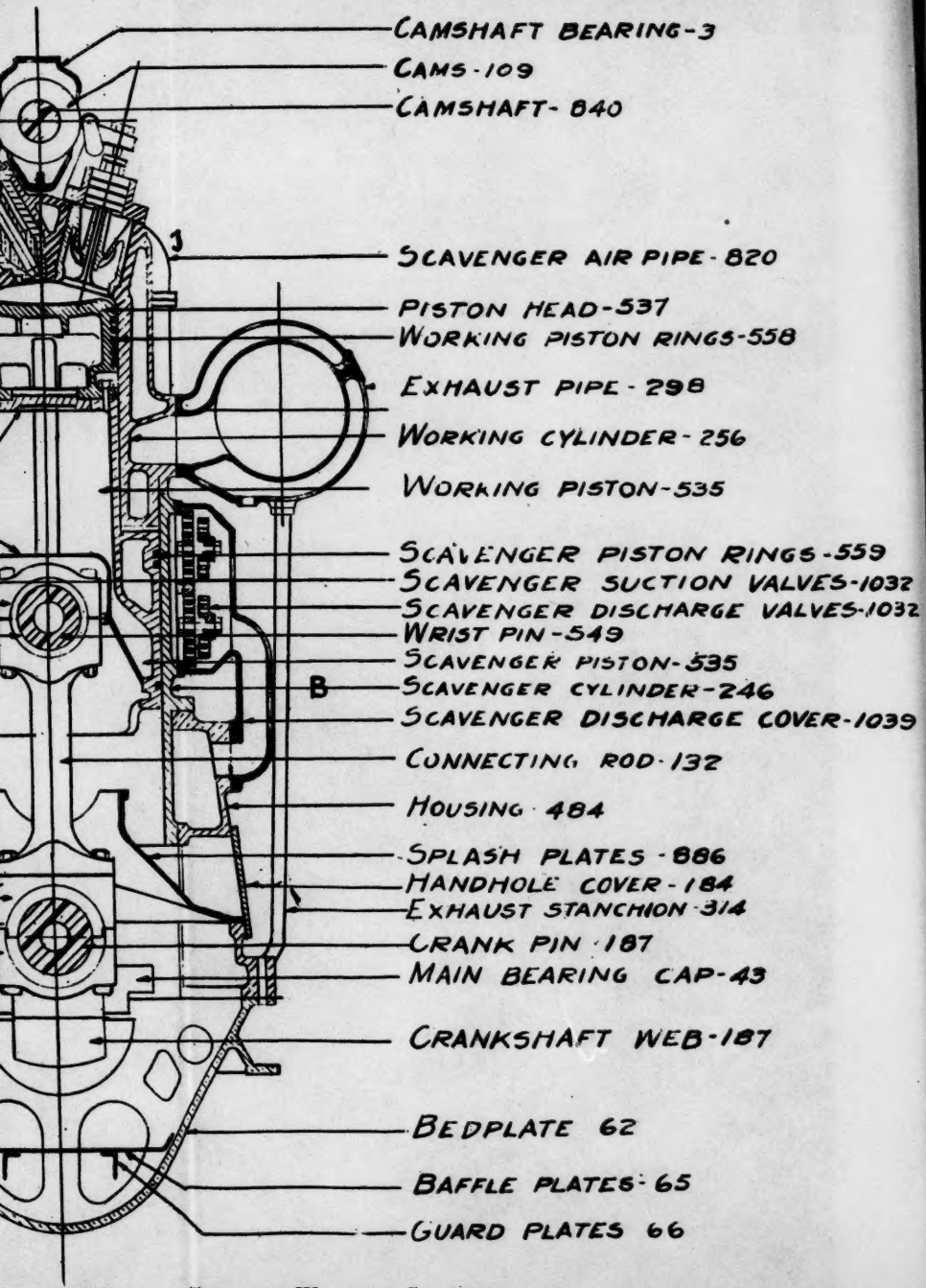
ATURE, MAIN PARTS OF ENGINE.



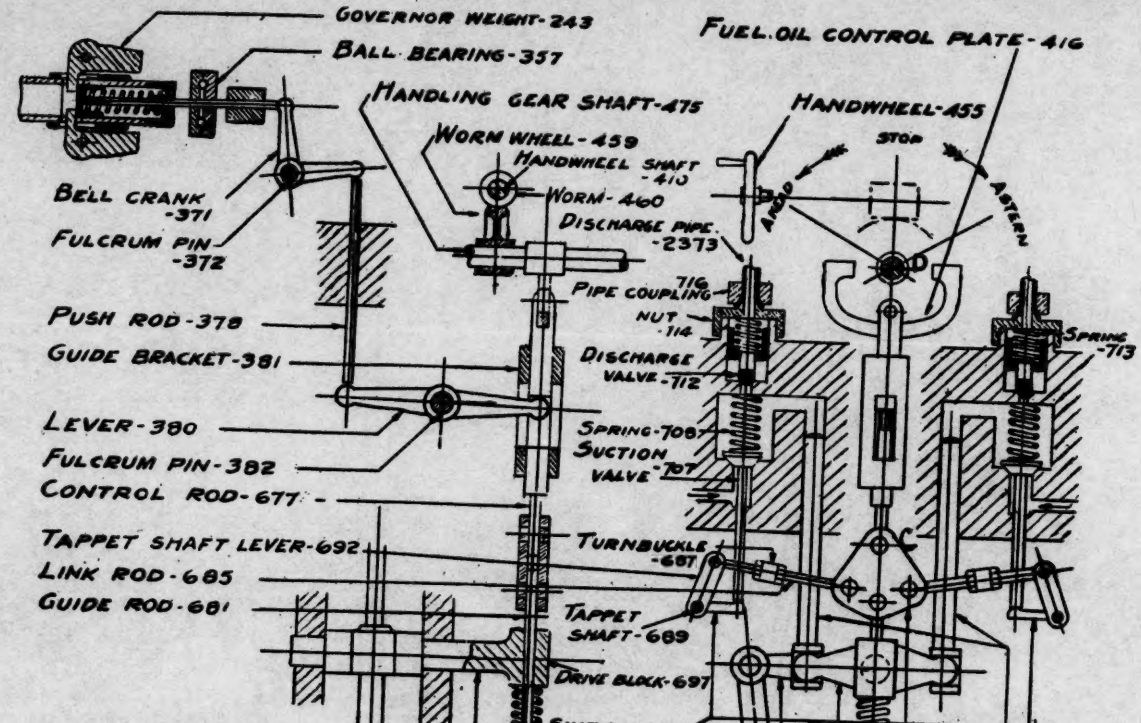
HROUGH AIR COMPRESSOR.

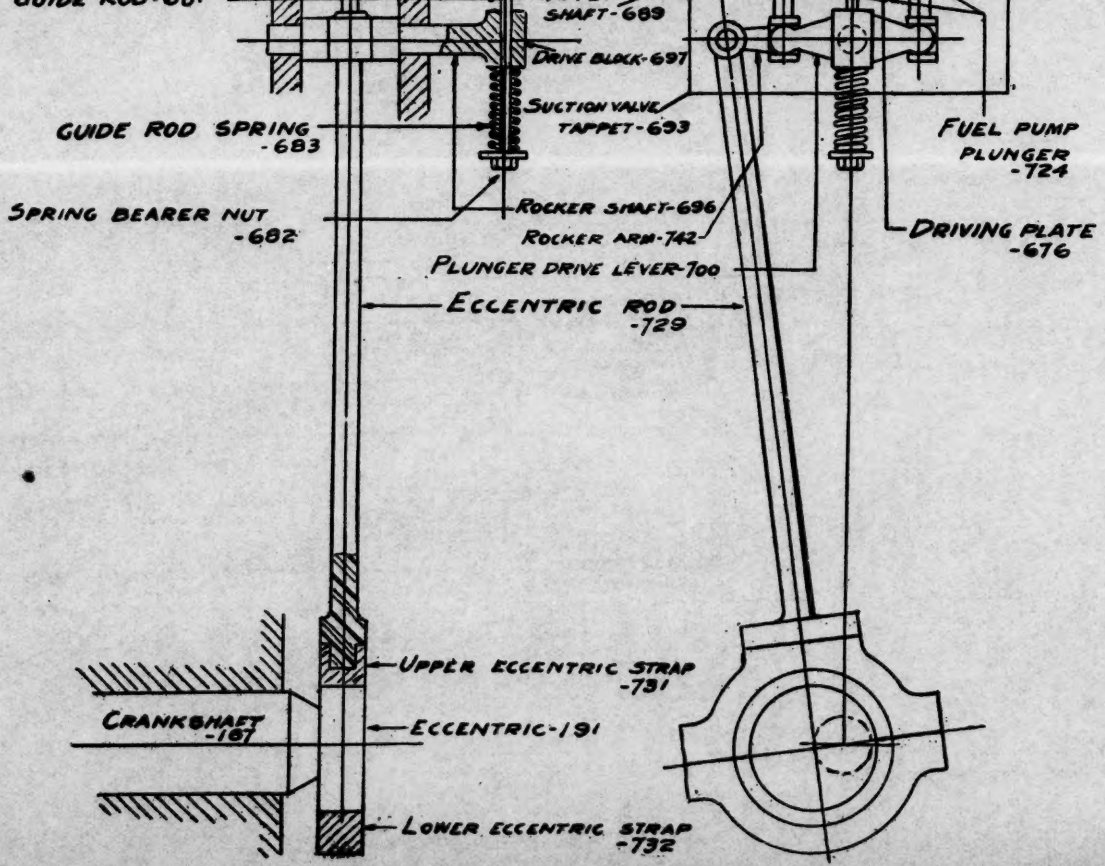
NOMENCLATURE, MAIN PARTS OF ENGINE.

SKETCH III.—S



CH III.—SECTION THROUGH WORKING CYLINDER.


GOVERNOR WEIGHT-243
BALL BEARING-357
HANDLING GEAR SHAFT-475
WORM WHEEL-459
HANDWHEEL SHAFT -410
WORM-460
BELL CRANK -371
FULCRUM PIN -372
DISCHARGE PIPE -2373
PIPE COUPLING 716
NUT -114
PUSH ROD-378
GUIDE BRACKET-381
DISCHARGE VALVE-712
LEVER-380
FULCRUM PIN-382
SPRING-708
SUCTION VALVE-707
CONTROL ROD-677
TAPPET SHAFT LEVER-692
LINK ROD-685
GUIDE ROD-681
TURNBUCKLE -681
TAPPET SHAFT-689
DRIVE BLOCK-697
FUEL OIL CONTROL PLATE-416
HANDWHEEL-455
STOP
AHEAD
ASTERN
SPRING -713



SKETCH IV.—NOMENCLATURE, FUEL-FEED PUMP AND GOVERNING MECHANISM.

ceiver. This merely acts as a reservoir, and no scavenger cylinder scavenges its own working cylinder. The scavenging air is lead through a pipe to the scavenger valve, and when that opens the air enters the cylinder and blows out the exhaust gases, the exhaust ports being uncovered during this period. As the scavenging is done with air and not with the fuel mixture as with the ordinary two-cycle gas engine, complete scavenging can be obtained and thus higher efficiencies. Besides, the scavenging valve can be put where the scavenging can best be effected. Also, while the actual volume of air is considerably less than the volume of the cylinder, the fact that this air is under 9 pounds pressure when the exhaust ports are closed gives this engine very close to the volumetric efficiency of the four-cycle engine, which has not a greater pressure at the same part of the stroke.

The engine has six cylinders, with one two-stage air compressor at the forward end. Each cylinder has its own scavenger cylinder (Sketch III), but each scavenger cylinder merely acts as a low-pressure compressor and discharges the air into a receiver (F, Sketch III), which supplies the scavenging pipes (J, Sketch III). There is a separate fuel-feed pump for each cylinder, which takes its motion from an eccentric on the forward end of the crankshaft (Sketch IV). The pumps and valves are together at the forward end of the engine, and discharge through small copper pipes into the spray valves. The fuel control is ingenious. The plungers of the fuel-feed pump-724 (Sketch IV), run at a constant stroke and discharge through spring loaded valves-712, into the pipe line-2373, to the spray valve. The suction valve-707, also acts as a regurgitating valve in connection with the plunger which, if open, allows the oil to return to the suction side of the pump. If the regurgitating or suction valve is open during the entire revolution of the engine no fuel will go into the engine, and the amount of fuel at each revolution is governed by the length of time the regurgitating or suction valve is open. This is accomplished with a driving plate-676, which governs the stroke of the suction valve and in this manner regulates the

opening. Fuel-oil control plate-416 (Sketch IV) governs the position of the driving plate-676. As the fuel-oil control plate revolves around D as a center, the center C, about which driving plate-676 oscillates, moves up or down. As the eccentric rod-729 moves up and down, the driving plate oscillates back and forth, making suction-valve tappets-693 move up and down. At the same time plunger-drive lever-700 oscillates and drives plungers-724 up and down a constant stroke. As the center C of driving plate-676 moves down the arc through which tappet shaft lever-692 oscillates will move toward the center, suction valve tappet-693 will oscillate lower down, and the suction valve will be closed during a longer portion of the stroke. As C moves up, the tappet-693 will oscillate higher up and keep the suction valve open during a greater portion of the stroke. While suction valve-707 is open, the fuel will go back to the suction line. When it is closed the oil must go on through the discharge valve-712. Consequently, the amount of fuel discharged is governed by the length of time the suction valve is open, and this in turn is governed by the position of center C of the driving plate. The governing is done with the same device. That is, a ball governor-243 on the cam shaft is attached through levers-371-372-378-381 and 380 to fuel-regulating device, and automatically regulates the opening of the regurgitating valve in the same manner as the fuel-control plate-416, and thus governs the engine.

The circulating water is pumped through reciprocating pumps on the forward end of the engine geared down from the main shaft to 4/9 revolutions of the main engine. There is also a fuel pump for pumping fuel into the suction of the fuel-feed pumps above described. This is run from the same crosshead from which are run the circulating pumps. All the handling gear pumps, etc., are on the forward end of the engine. The lubricating-oil pump is also run from this crosshead. The cylinder-lubricating oil is forced under pressure by a special lubricating manifold run from the vertical cam shaft by spiral gearing on the after end of the engine.

The cam shaft is run from the main shaft by means of

spiral gearing and vertical shaft. On the cam shaft are the spray cams, the scavenger cams and the air-starting cams. The reversing is accomplished with compressed air. The vertical shaft has a special coupling with a 30° blank. On reversing, the upper section remains stationary till the lower section has turned through 30° when all cams are then in position for motion in the opposite direction. For example: the spray valve begins to open when the crank is 2½° in advance of the top center and closes when the crank is 32½° beyond the top center. This gives an opening of the spray valve through 35°. Now by shifting the cam shaft back 30° by means of this clutch, the spray valve will begin to open 2½° on the opposite side and remain open beyond the stroke 32½° in the opposite direction, thus reversing the functions of the spray. The scavenging cams are reversed by the same action of the clutch and cam shaft.

The reversing is accomplished by separate cams and reversing valve, or air-starting valve, which is the same for either direction. The following is an extract from Patent No. 1,005,507, a perusal of which will facilitate the understanding of the description of the handling gear.

Figure 1 is a diagram, showing in section part of the engine cylinder with the starting valve, the distributing valves, the operating members therefor and the compressed air vessel; Fig. 2 is a similar diagram to Fig. 1, showing a modification.

a is the starting valve, the cone of which is held in closed position by a spring *b*. The upper part of the valve cone is formed as a piston *c*. The conduit *d* from the compressed air vessel A opens laterally into the casing of the starting valve. Above the piston *c* the starting valve is connected by the conduit *e* with the two distributing valves *f* and *g* which communicate respectively through the conduits *h* and *i* with the operating members *k* and *l*. A conduit *x* connected with the conduit *d* runs to the operating members.

The engine is started in the following manner:—In Fig. 1 the compressed air vessel A is opened and either the operating member *k* or *l* actuated by the operating lever *m*. The

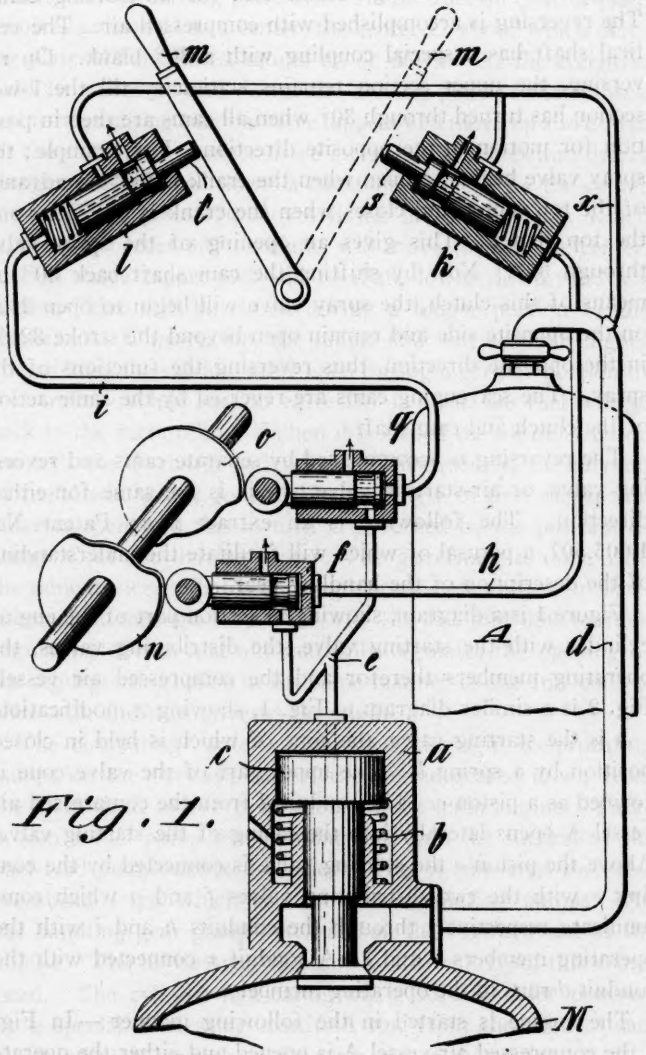


Fig. 1.

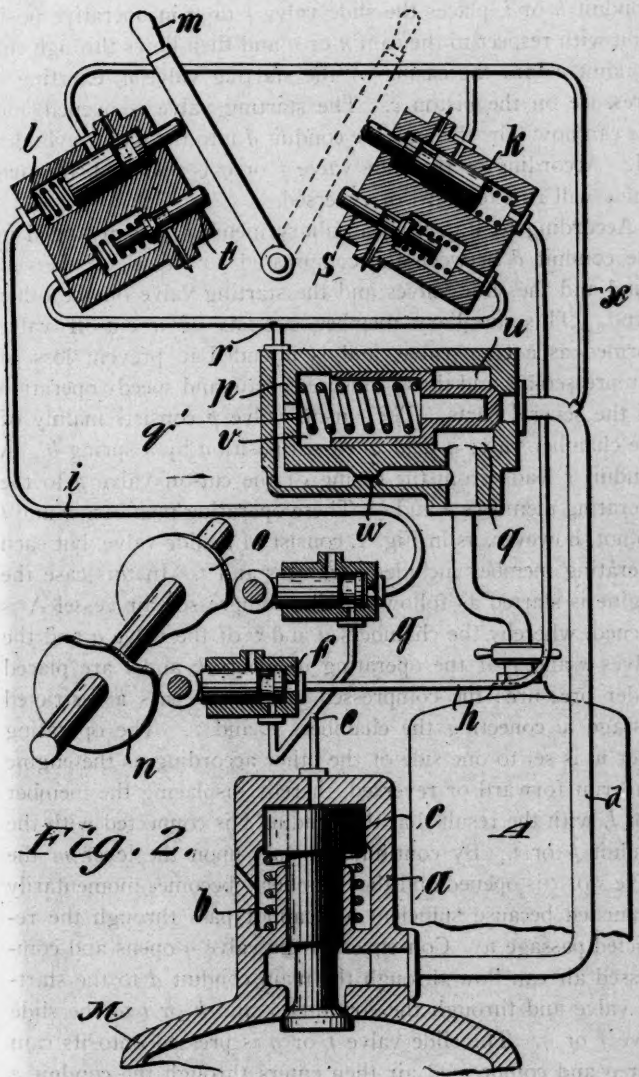
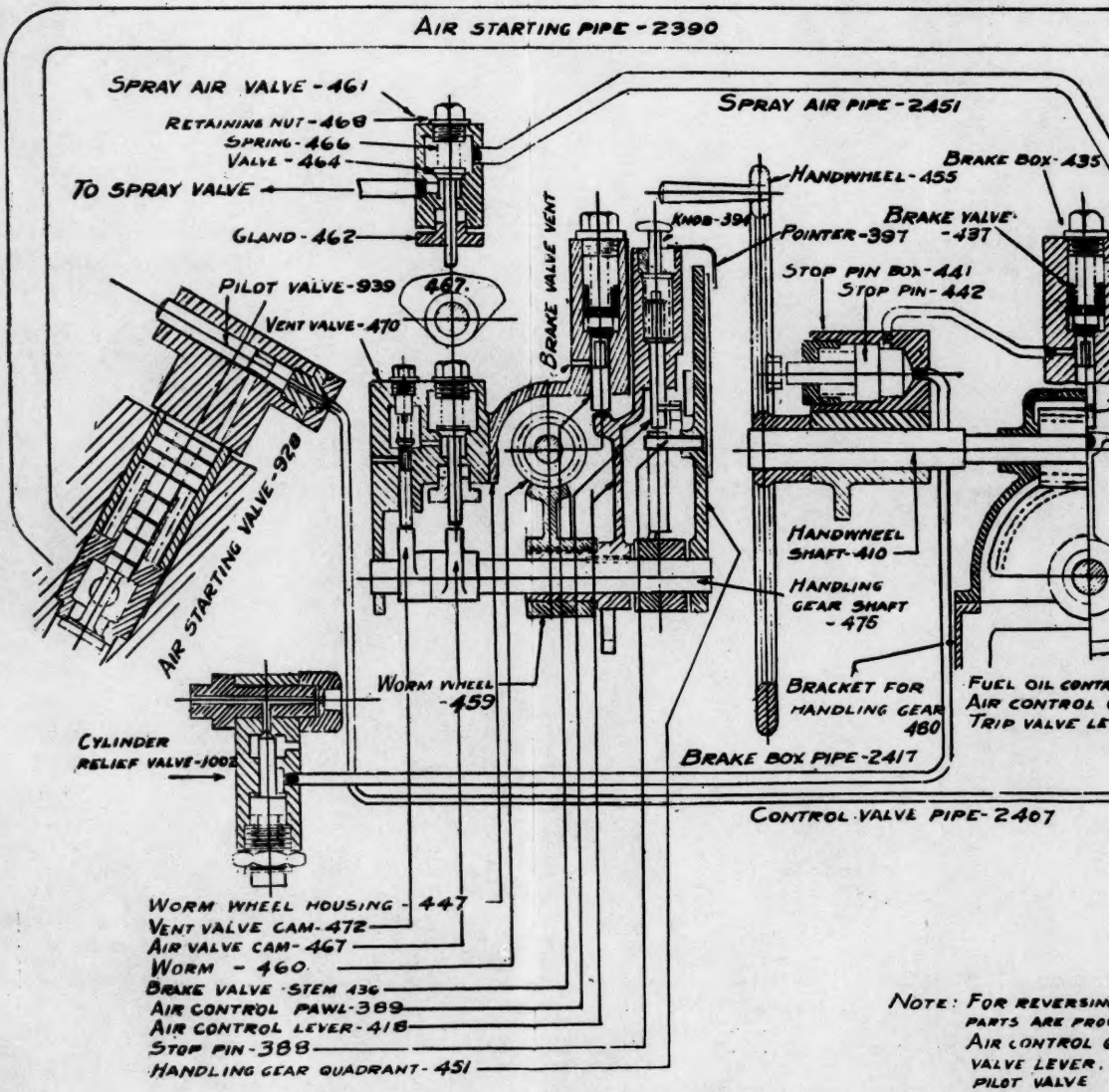


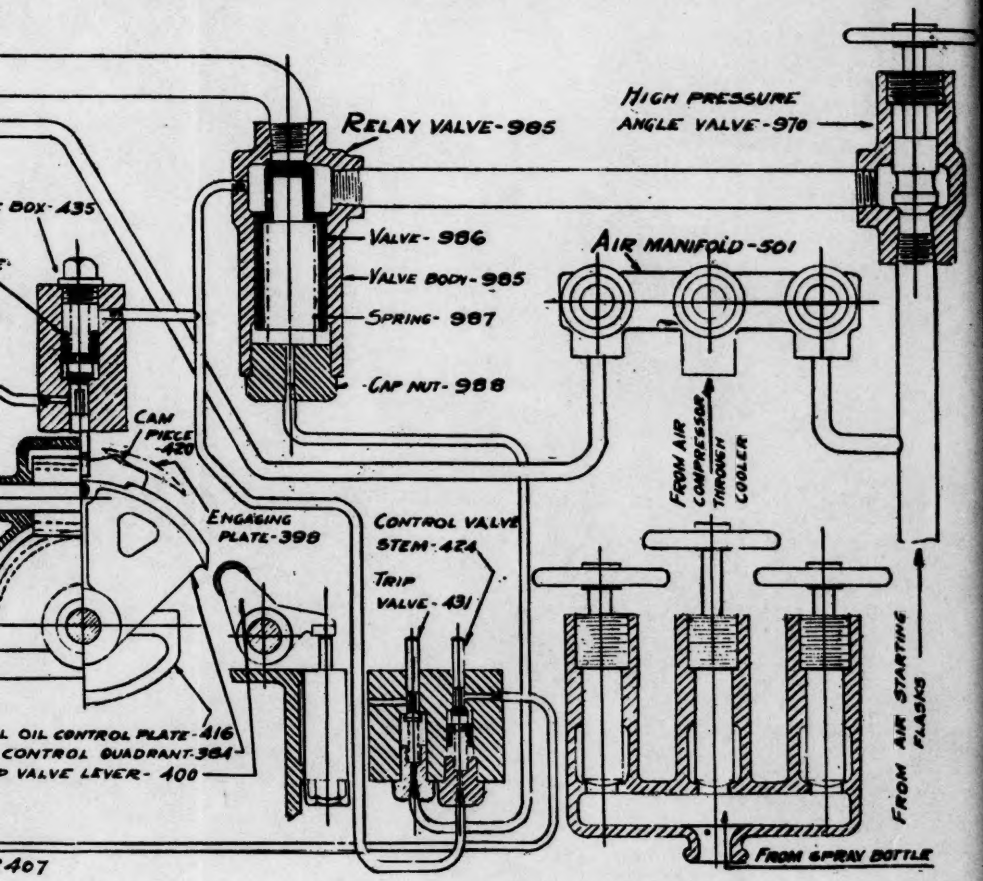
Fig. 2.

air then flows through the operating member *k* or *l* into the conduit *h* or *i*, places the slide valve *f* or *g* in operative position with respect to the cam *n* or *o* and then flows through the conduit *e* into the casing of the starting valve *a*, exerting a pressure on the piston *c*. The starting valve is opened and air can now flow through the conduit *d* into the motor cylinder M. According as the slide valve *f* or *g* is operated, the machine will run forward or reversed.

According to Fig. 2 an auxiliary member *p* is arranged in the conduit *d* between the compressed air vessel on the one hand and the slide valves and the starting valve on the other hand. This auxiliary member consists of a cut-off valve formed as a cone valve, and is intended to prevent loss of compressed air and thus to insure certain and speedy operation of the several parts. The cut-off valve *p* consists mainly of the chamber valve *q* held in closed position by a spring *b*. A conduit *r* leads from the casing of the cut-off valve *p* to the operating members *k* and *l*. These operating members *k* and *l* do not, however, as in Fig. 1, consist of a slide valve, but each operating member includes a valve *s* and *t*. In this case the engine is started as follows:—The compressed air vessel A is opened, whereby the chambers *u* and *v* of the valve *q* and the valves *s* and *t* of the operating members *k* and *l* are placed under pressure: the compressed air has to pass a restricted passage *w* conecting the chambers *u* and *v*. The operating lever *m* is set to one side or the other according as the engine is to run forward or reversed, thereby displacing the member *k* or *l*, with the result that the conduit *x* is connected with the conduit *h* or *i*. By continuing to act upon the lever *m* the valve *s* or *t* is opened and the chamber *v* becomes momentarily exhausted because sufficient air cannot pass through the restricted passage *w*. Consequently the valve *q* opens and compressed air can flow through the main conduit *d* to the starting valve and through the conduits *x* and *h* or *i* to the slide valve *f* or *g*. The slide valve *f* or *g* is pressed onto its cam *n* or *o* and compressed air then enters through the conduit *e* the casing of the starting valve, exerting pressure against the



SKETCH V.—NOMENCLATURE, H



REVERSING THE ENGINE, THE FOLLOWING
S ARE PROVIDED BOTH FOR "AHEAD" AND "ASTERN"
CONTROL QUADRANT, ENGAGING PLATE, TRIP
VE LEVER. CONTROL VALVE, TRIP VALVE. AND
T VALVE

ATURE, HANDLING GEAR.

piston *c*. The starting valve opens and will remain open so long as the slide valve *f* or *g* permits of communication between *i* or *h* and *e*. When the slide valve is pressed back by its cam *n* or *o*, the conduit *e* will be in communication with the atmosphere, the starting valve will be relieved and closed under the pressure of its spring *b*. If the engine is running forward and it is to be reversed, the starting valve is actuated in the manner indicated by the reversing block. The lever *m* is arranged in such a manner that in addition to the reversing gear it actuates the fuel pumps and enables the supply of fuel to be cut off during reversing. The starting air first acts in opposition to the movement of the engine, acting as a brake and then causes the engine to rotate in the opposite direction.

DESCRIPTION OF HANDLING GEAR AND REVERSING GEAR.

The operation of the handling gear is as follows: (see Sketch V).

The first operation is to open all valves in manifold-501, and high-pressure angle valve-970. In the manifold the left valve allows air to go to the spray air relay valve-461. The middle valve opens to the compressors and the right-hand valve to the air-starting flasks. Air then backs up from the air-starting flasks to the top of the compressor piston. High-pressure angle valve-970 allows air to go to the relay valve-985, to the pipe on the opposite side, air going to the top of brake valve-437 and under control valve-424. At the same time air enters through a small hole shown in the valve-986, through pipe in cap nut-988 to trip valve-431. All this has been accomplished by opening the three valves in air manifold-501 and high-pressure angle valve-970. The handling gear is now in position for operating the engine, and these valves are always open when the engine is operating or ready to operate.

In order to start the engine in either direction, turn the hand wheel-455 in the required direction. This wheel turns a worm-460 which operates worm wheel-459, to the axis of which the various cams, etc., are fixed. As this axis revolves,

cam-420 lifts brake valve-437, the plunger underneath which first closes the brake-valve vent. Air then enters stop-pin box-441 and drives stop pin-442 out, preventing the handle from making more than one revolution till the air is released after pressures are relieved in cylinders. At the same time air enters brake-box pipe-2417 and on top of piston in cylinder-relief valve-1002, forcing open the valve and allowing what pressure there is in the cylinder to release. As hand wheel is turned cam-420 goes by the brake valve, closing the valve and venting the line. This releases the air pressure in stop-pin box and brake-box pipe, allowing spring to force stop pin-422 back and seating the relief valve-1002. As the hand wheel is turned a projection on air-control pawl-389 catches under an engaging plate-398, which allows the bottom of pawl-389 to engage air-control sector-384, forcing it to turn on the same axis. The forward edge of this sector pushes the bell-crank lever-400 over, pushing down and opening first, trip valve-431 and then, control valve-424. When this is done air is released through trip-valve vent shown from underneath relay valve-985 (the opening in valve being much smaller than vent in trip valve.) The difference in pressure opens the relay valve allowing air to go to air-starting valve-928 through air-starting pipe-2390. This brings starting air to each cylinder. As soon as control valve-424 is open air is admitted to control-valve pipe-2407 and behind the plunger or pilot valve-939. (There are two pilot valves and air-starting cams on each cylinder, one for ahead and the other for astern; only one is shown in the figure.) One or two of the air-starting cams are in such position that the air back of the pilot valve forces it forward far enough so that the inner end uncovers the port to the top of piston of the air-starting valve-928, forcing the valve open and allowing air into the cylinder, thus starting the engine, the other cylinders taking up the motion in rotation. Just as the air-starting gear has the engine going at the requisite speed, spray-air-relay valve came-467 opens spray-relay valve-461, first closing vent valve-470, which allows spray air to go to the main

spray valve on the cylinder, starting the engine on fuel. Just as this is accomplished the projection on air-control pawl-389 disengages from engaging plate-398, the spring forcing it up, releases sector-384, which flies back closing trip valve-431 and control valve-424. This again closes relay valve-985, shutting air off air-starting valves-928. As control valve-424 is closed small vents are opened and release pressure in control-valve pipe-2407, the pilot valve-939 being forced back from the cams. Just before the spray-air-relay valve-461 is opened fuel-oil control quadrant-416 is in position to allow fuel to be forced into the fuel pipes. The engine is now running under fuel, all the air-starting mechanism being disengaged. The speed varies with the distance through which the hand wheel is turned. The farther over the wheel is turned the greater amount of fuel is pumped into the spray valve at each revolution, the fuel-oil control plate-416 regulating this by regulating the position of the stroke of the suction or regurgitating valve of the fuel-feed pumps.

The working and scavenger cylinders are of cast iron, but for lightness the housing and bedplates are of bronze. Sketch III shows that the scavenging and working cylinders are separate castings in this type of engine. The working cylinder-256 is water jacketed, as is the exhaust pipe-298. The air-starting, spray and scavenging valves, are not jacketed. The piston head (A, Sketch I) is oil cooled. The oil from the wrist pin D enters a hole E inside the piston, flows through the head, and out through another hole F on the opposite side of the piston, through a pipe G that is lead clear of the wrist pin and into the crankpit. The piston is made in two sections. Lower section B includes the body of the working piston and the whole of the scavenging piston, while the upper section A is the piston head. This construction was adopted because of the trouble experienced with the core plugs in the top of the piston where the single-casting type had been used. After a certain length of time these core plugs would come out, in spite of all precautions taken with their installation, and cause considerable damage. With the

two-section type the holding-down bolts are in recesses in the side, and never come into contact with the hot gases, and, as the top has no holes of any description, there is now no trouble with core plugs loosening. The upper section is large enough to take all of the piston rings. The wrist pin D is secured in the scavenging piston and thus is not exposed to the heat of the working cylinder. This is a great advantage in that it is not difficult to keep wrist-pin bearings cool.

Several of these engines have been given very severe tests, one of them a full-power test of twenty-eight hours. The lubricating system seems to be very well designed, for, while fourteen of these engines have been tested, there has not been a single case of hot bearings. A copy of the record of a six-hour test of one of these engines follows. It will be seen that the powers are very uniform. In testing, the engine drives a generator and the power generated is absorbed by large pipe resistances which are cooled by water circulating through them. While the test is under way the volt and ammeter pointers scarcely move, showing how well the fuel feed is regulated.

REPORT OF TEST.—FIRST THREE HOURS.

ENGINE, 75-6. TYPE, H.S. NO. 103. DATE, 12-17-12.

Time	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	5:30
Revolutions	450	450	450	450	450	450	450	450	450	450	450	450	450
Volts	210	210	210	210	210	210	210	210	210	210	210	210	210
Ampères	1475	1475	1475	1470	1470	1470	1470	1470	1470	1470	1470	1470	1470
H.P.	443	443	443	441	441	441	441	441	441	441	441	441	441

Consumption.—Total for run.—*First three hours:*

Oil, 13.5 gallons ..... rate... Gallons per minute..... 26
Water, 14,760 gallons..... rate... Gallons per minute 82
Fuel, 105 gallons..... rate... Pounds per H.P. hour.. 0.57

Adjustments:
A.C. control, wide open.
Control lever, $2\frac{3}{16}$ turns.
Size of spray nozzle, .187.
Fuel oil, lot No. 2, western oil.
Lubricating oil, trade name, Autoline, No. 2.

Condition of exhaust:
White smoke at end of pipe.
Brown vapor at 3-inch try valve.

Pressure, pounds:

Air pump, first stage	105	105	105	105	105	105	105	105	105	105	105	105	105
Spray air	875	900	900	900	900	900	900	900	900	900	900	900	900
Scavenger receiver	9½	10	10	10	10	9	9	9	9	9	9	9	9
Oil	44	45	45	45	42	44	42	42	43	42	42	44	43
Water	8	7½	7½	7½	8	7½	7	7	7	7	7	7	7
Auxiliary fuel	5	5	5	5	5	5	5	5	5	5	5	5	5

Temperatures, degrees F.:
Exhaust, not taken.

Water inlet	46	46	46	46	46	46	46	46	46	46	46	46	46
outlet	90	90	90	90	90	90	90	90	90	90	90	90	90
Oil inlet	65	85	90	96	100	100	100	100	100	100	100	100	100
outlet	130	142	150	158	162	167	164	164	162	160	160	160	160
Scavenger receiver	147	152	180	200	212	206	204	200	198	198	198	198	198
Atmosphere	68	68	68	68	68	68	68	68	68	68	68	68	68
Crankpit	130	140	160	170	174	176	166	164	164	162	162	162	162

Remarks.—At the end of 1 hour the relief valves on the scavenger receiver were set at 9 pounds.

REPORT OF TEST.—SECOND THREE HOURS.

ENGINE, 75-6. TYPE, H.S. NO. 103. DATE, 12-17-12.

Time	5:45	6:00	6:15	6:30	6:45	7:00	7:15	7:30	7:45	8:00	8:15	8:30
Revolutions	450	450	450	450	450	450	450	450	450	450	450	450
Volts	210	210	210	210	210	210	210	210	210	210	210	210
Ampères	1470	1475	1470	1470	1470	1470	1470	1470	1470	1470	1470	1470
H.P.	441	443	441	441	441	442	441	441	441	441	441	441

Consumption —Total for run.—*Second three hours:*

Oil, 13.5 gallons.....rate... Gallons per minute..... 26
Water, 14,760 gallons.....rate... Gallons per minute..... 82
Fuel, 100.5 gallons.....rate... Pounds per H.P. hour..... 0.55

Adjustments:
A. C. control, wide open.
Control lever, 2½ turns.
Size of spray nozzle, .187.
Fuel oil, lot No. 2, western oil.
Lubricating oil, trade name, Autoline, No. 2.

Condition of exhaust:
Same as first three hours.

Pressures, pounds:

Air compressor, first stage	105	105	105	105	105	105	105	105	105	105	105	105
Spray air	900	900	900	900	900	900	900	900	900	900	900	900
Scavenger receiver	9	9	9	9	9	9	9	9	9	9	9	9
Oil	45	43	45	43	43	43	43	43	43	43	43	43
Water	7	7	7	7	7	7	7	7	7	7	7	7
Auxiliary fuel	5	5	5	5	5	5	5	5	5	5	5	5

Temperatures, degrees F.:
Exhaust, not taken.

Water inlet	46	46	46	46	46	46	46	46	46	46	46	46	46
outlet	90	90	90	90	90	90	90	90	90	90	90	90	90
Oil inlet	100	100	100	100	100	100	100	100	100	100	100	100	100
outlet	160	160	160	158	158	158	158	158	158	158	158	158	158
Scavenger receiver	198	198	198	198	198	198	198	198	198	196	196	196	196
Atmosphere	68	68	68	68	68	68	68	68	68	68	68	68	68
Crankpit	160	160	160	158	158	158	160	160	158	158	158	158	158

Remarks —During the last 3 hours not a single adjustment was made on engine or switchboard.

NOTES.

THE CRUISING ELEMENT IN WARSHIP MACHINERY.

One of the ever-recurring problems in connection with the design of warship machinery has reference to the attainment of the maximum radius of action, especially at cruising speed, for a given supply of fuel. It is an old adage that wars are made up of six months' marching and one day's fighting, and thus battles on land are often won by the shoemaker. So also with sea fighting: warships may cruise for days in search of the enemy, and when the crucial moment arises victory may very largely depend upon the amount of fuel remaining in the ships of the squadron, in order that the highest speed desired by the tactician may be realized. This applies particularly to the torpedo-boat destroyer and the scout cruiser, and consequently a keen interest is being taken at the present time in several alternative methods of improving economy at low power.

It has been the practice to assume that the difficulty only arose with the adoption of the steam turbine. It is well known that its economy is largely due to the blade speed approximating to a definite ratio of the velocity of the steam, and that with a reduction in the number of revolutions the economy falls off. But even with the reciprocating engine the designer was beset with difficulties to achieve economy at great ranges in speed, and the proportions of the multiple-expansion cylinders were arranged, in some cases, to give a greater economy at lower rates than at full power. With the advent of the turbine the desire for higher speed was whetted, because of the great potentialities of the turbine in this direction, and for a time there may have been some disposition not fully to strive for the desideration of a great radius of action at cruising speed. Experience has shown that economy is sometimes assisted by the introduction of the impulse wheel, with multiple nozzles, to vary the volume of the steam passing through the turbine and the power to be developed, by cutting out nozzles instead of by throttling down. Again, separate turbines have been added to the ordinary full-power installation, so that the blade speed of the separate turbine may meet requirements and the range of expansion be increased by the use of the steam in these turbines before passing into the ordinary high-pressure machine of the full-power installations. This also increased the economy at low powers, but there is the disadvantage that weight has to be carried which is of no value when running at full speed. This additional weight in machinery, however, bore a small proportion to the total saving in the weight of fuel for a given radius of action at cruising speed, and the practice will probably be extensively adopted.

The increasing reliability of the oil engine has suggested its adoption instead of the cruising turbine, because its consumption of fuel is very considerably less. In the case of two destroyers being built by Messrs. Yarrow such an application is probably reduced to its most simple form. The internal-combustion engines are to be of the non-reversible type. Speed is transmitted to the shaft through a Föttinger hydraulic transmitting gear, by which the rate of revolution or the direction may be varied at will. The shaft operated by the internal-combustion engine

passes through the hollow shaft of the steam turbine, being connected abaft it to the propeller shaft by means of a clutch. Thus at cruising speed, with the oil engine in action, the turbine need not rotate, so that no vacuum need be maintained in the condenser. These destroyers are similar to three very successful vessels—those of the *Firedrake* class—built by Messrs. Yarrow for the British Navy, which have a length of 255 feet and a displacement of 765 tons, and with which a speed of over 35 knots was realized. The installation of the oil engine for cruising, it is estimated, will give a radius of action of 700 sea miles at full speed and of 8,000 sea miles at half speed; but the maximum speed obtainable is reduced practically to the extent of 1½ miles per hour, the weight of the machinery being augmented by about 100 tons, equal to nearly 25 per cent., and the space occupied by 15 per cent., involving an addition to length and displacement of the vessel. The problem thus becomes one for naval officers to decide: whether they prefer the radius of action increased for a given fuel supply, or to have the higher maximum speed with the less radius of action; that is to say, is it worth a reduction of the full speed by 1½ knots to secure four times the radius of action?

There is, however, another serious objection from the tactical point of view. A warship is built to fight, and must be ready to fight at any moment; every consideration, even economy, is subservient to this dominant requirement. If a destroyer is cruising in war time with an oil engine, steam will require to be up in the boilers and the turbines kept heated, so that at the crucial moment the destroyer may, like a dog let loose from its leash, spring after the enemy. Thus the theoretical tactical advantage of the economy of the oil engine for cruising may not be borne out in war practice, since the steam installation may not then be completely out of action.

For the purpose of indicating the relative tactical advantages of various systems of cruising elements, we take first a typical present-day destroyer, fitted with the normal type of turbine machinery without a cruising turbine. Such a vessel might carry 200 tons of oil fuel, which at a given cruising speed would enable her to have a radius of action equal to 2,000 nautical miles. The maximum speed with the tanks full would be 32 knots, but as the 200 tons of oil gradually became consumed in the boilers the speed would go up to 35 knots, and it would be possible, with 200 tons of oil, for the vessel to steam for twenty hours at the maximum speed. By adding an internal-combustion engine to achieve economy at cruising speed, the 200 tons of oil might give a radius of action, at the same cruising speed, equal to 8,000 nautical miles; but, because of the increase of weight of about 100 tons involved in the internal-combustion engine, the maximum speed would be reduced 1½ miles, to 30½ knots. But there would be the same acceleration due to the lighter load consequent upon the consumption of the oil, so that the maximum speed when the oil tanks were nearly empty would be 33½ knots. The time during which full speed could be maintained would still be 20 hours. If, on the other hand, the 100 tons involved in fitting a Diesel engine were utilized to add to the oil-fuel supply in the destroyer with turbine machinery, the result would be a radius of action of 3,000 miles instead of 8,000 miles, the maximum speed would not be affected when the tanks were full, being still 30½ knots. The 300 tons of oil would enable the ship to travel for 30 hours instead of 20, and at the end of that time the maximum speed would be 35 knots, instead of 33½ knots as in the case of the destroyer with the oil engines. As already mentioned, it thus becomes very largely a question of the extent of cruising aimed at before possible action, or the distance between the base and the enemy's fleet or frontier.

We come now to a consideration of the effect when cruising turbines are fitted in addition to the main propelling turbines. The weight would be considerably less than in the case of the oil engine, and for the same

displacement it would be possible to have, in addition to the cruising turbine, about 280 tons of oil fuel, instead of 200 tons with the Diesel engine. Thus the radius of action would be a little more than half that of the destroyer with internal-combustion engines for cruising—namely, 4,500 nautical miles. As the displacement would be the same, the maximum speed when the tanks were full would be the same—30½ knots; but when they were emptied it would be higher—34½ knots; while the time during which full speed could be maintained would be 28 hours. Were superheating to the extent of 100 degrees adopted for the cruising turbines, as seems very probable in the near future, the radius of action might be increased to 5,000 sea miles; but, of course, this would not affect the maximum speed or the period during which it could be maintained.

The comparison, so far as the cruising turbine and cruising internal combustion engine are concerned, may thus be briefly stated. Assuming that the same weight is allowed in both destroyers, in the one case for the Diesel cruising engines, main propelling turbines, and oil fuel, and in the other for cruising and main turbines and oil fuel, and adopting 100 per cent. superheat, the radius of action would be 8,000 miles in the former and 5,000 miles in the latter case. The maximum speed at full load would be the same—30½ knots; but the Diesel-engine ship would only be able to run for 20 hours at this maximum speed, equal to something like 640 nautical miles, the highest rate being 33½ knots; whereas the ship with all-turbine installation would be able to run for 28 hours at the maximum speed, covering 890 miles, and her speed at the end of the run would be 34½ knots. It seems, therefore, as if on balance the advantages were distinctly in favor of adopting the cruising turbine, and of using superheated steam; because, although there is some loss in the radius of action at cruising speed, there is gain in the rate of speed during a prolonged full-speed run, as well as the possibility of covering nearly 50 per cent. more ground at full speed.

There are great developments possible with gearing, as some of the thermodynamic difficulties of running the turbines at low speed may be minimized, particularly as at full speed the rate of revolution can be very high without involving too great a speed for the propellers. At present there are being built vessels with gearing on all shafts, whereas in service there are vessels with gearing on the cruising turbine only. The results of the performance of such vessels will be watched with great interest, because they reflect on a problem which is important as well as fascinating.—"Engineering."

OIL-FIRED SHIPS OF WAR.

Oil firing in the Navy is a subject which may, and indeed must, be looked at from more than one point of view. Of its advantages there can be no question. Oil increases the radius of action, it eases the work of stoking it is more easily taken on board, it gives greater speed. Ships of the *Queen Elizabeth* class could not be what they are were it not for oil. All these things we know, and they are apt to blind us to the drawbacks to the use of oil in the British Navy. The greatest of these is the fact that, save for a very small amount, no oil is found or produced in these islands. We have to look to foreign lands for our supplies; the oil we use has to be brought over many miles of sea. Hence millions of tons must be stored, lest in the event of war we should find our vessels made useless by the lack of fuel. The stores have to be protected against hostile attack, and they are more difficult to safeguard than are stacks of coal. All this is common knowledge. What we have to ask ourselves is whether or not the disadvantages which attach to the use of oil are

balanced by its advantages. Mr. Churchill appears to have made up his mind that they are, for he has ordered a number of vessels to be fitted only for the use of liquid fuel, not, as heretofore, either for coal or oil. He has possibly been led to this course by the reports of the Royal Commission. The reports are confidential, and not for many years will the public know what they contain; but it is probable that they are concerned more with the technicalities of the use and storage of liquid fuel than with such a debatable subject as the wisdom of employing it. That is a matter which the Lords of the Admiralty and the Government must settle.

There are one or two aspects of the question to which we invite attention. It is not too much to claim that what the British Navy does today the other navies of the world will do tomorrow. If we decide to throw over coal altogether they also will do the same. What must be the result? The advantages of liquid fuel will no longer be enjoyed by us alone; they will be shared by the whole world, and we shall cease to benefit by them. Increased speed is of little value to us if Germany, France, Russia, Austria, Italy, America, and so on, have the same speed. We can get no tactical advantage. Whether the maximum battleship speed is twenty knots or thirty knots matters little if it is the same for all nations. Radius of action may, conceivably, be of more importance to one nation, or one fleet, than to another. The British Navy has a great area of high seas to cover, hence it may mean more to her than it does to Austria or Italy, for example. It may be worth giving up a good deal to secure that advantage. The Admiralty alone is in a position to decide. Take, again, the ease of loading up oil "bunkers." It appears highly attractive, but we have to remember that the medal has another face. The very properties we praise may, under adverse circumstances, prove our undoing. If oil replaces coal we lose not only the protection that coal affords—slight as it is, it is worth having—but we have even to take special pains to protect our fuel. It must be carried below the water line lest a lucky shot or some misfortune should pierce the tanks and empty the contents into the sea; all the pipes that convey it to the boilers must be placed absolutely out of harm's way, and great precautions to see that they are all in absolute working order must be taken. An accident which would cause no more than inconvenience on a coal-fired ship might put an oil-fired ship out of action. The storage and use of coal at sea is crudely simple. There is little or nothing that can go wrong. Certainly nothing that can make it impossible to keep some steam in the boilers. The use of oil is more complicated, and every complication means additional danger of something going amiss.

Great as are the advantages of oil, it is quite an open question whether they outweight the drawbacks. If we alone of all the nations of Europe were in possession of an inexhaustible supply of oil, then our right course would not for a moment be in doubt. Oil we should use as a matter of course. Oil we have not got, but we have the best steam coal in the world. In that respect we are better placed than any other navy. In the event of a prolonged war when their stores of Welsh coal were exhausted we should still have an unlimited supply. Are we wise then to throw up such an advantage? Are we wise to lead nations which are still content to use our coal to use a fuel which we lack and the use of which must put us on equal terms with them? These are hard questions to answer. The intentions of other nations may be so clear to the First Lord that he may have had no other course than to order all oil-burning ships. If they are not, we must look with doubt upon the course he is following. The combination of coal and oil firing has much to commend it; oil firing alone, on the other hand, has much in it to give us grave anxiety. That anxiety is doubled, for the present, by the fact that it does not appear that full arrangements have yet been made for securing the

large supply our Navy will need. Surely it would at least have been wise to make certain of the supply before the step of ordering the ships had been taken.—"The Engineer."

A NEW STEAM ENGINE SUITABLE FOR STEAMERS.

By Thos. Osborn.

An entirely new departure in steam-engine construction seemed scarcely possible after the introduction of the steam turbine, which would be equally suitable for navigation and industrial purposes. The una-flow steam engine is, after the turbine, the most novel and important departure from the known and normal lines of steam-engine construction which has been submitted to the public during the last generation. The inventor is the widely known Professor J. Stumph, one of the staff of the Technical High School, Charlottenburg, near Berlin. The broad idea underlying the invention has suggested itself to other inventors. A patent was taken out in Great Britain as far back as 1885 by Mr. J. L. Todd for a una-flow engine. No results were obtained by the inventor, he was in advance of the times; but since Professor Stumph took up the subject, not so many years ago, very considerable progress has been made, as there are now engines working on the new principle, to over half a million horsepower. The una-flow engine is a reciprocating machine, but from the thermal point of view it bears some relation to a steam turbine. In the ordinary reciprocating engine steam enters by a port at one end of the cylinder and is exhausted through the same or another port at the same end of the cylinder. It follows that when the exhaust valve opens there is a rush of steam towards what has been the inlet end a moment earlier. This exhaust steam is relatively cold, and, because of its low temperature and high velocity, exercises a strong cooling influence on the cylinder cover, also to a lesser extent upon the walls of the cylinder. This cooling leads to initial condensation and loss of thermal efficiency. The new engine is worked as follows: The exhaust takes place through a ring of ports cut in the cylinder barrel just before the end of the piston stroke; in its outward motion the piston uncovers these ports and allows the steam to escape to the condenser or the atmosphere. On the return stroke the piston closes the ports and compresses the steam left in the cylinder, the clearance space being normally chosen so that compression takes place to about the initial steam pressure. By these means the rush of cold steam past the hot metal in the neighborhood of the inlet valve is avoided, and consequently also the contact of hot high-pressure steam with the walls cooled by the rush of cold exhaust steam. The steam under this system is bound to flow *in one general direction*, although only intermittently and not continuously as in a turbine, that is from inlet to exhaust without retracing its path. By this device condensation losses are reduced to a minimum.

In the engines constructed in accordance with Professor Stumph's invention the complete expansion takes place in one cylinder, so that the receiver losses, which are unavoidable with a compound or triple-expansion engine, are entirely eliminated. There are thus two very definite and important advantages which the new una-flow engine possesses over the ordinary, or alternating-flow, engine. On the other hand, the clearance losses in a una-flow engine are necessarily high, seeing that the exhaust ports are closed by the returning piston and the compression of the entrapped steam begins when only one-tenth of the exhaust stroke has been made. Many Continental engineers of standing have expressed the opinion that compression to boiler pressure eliminates the losses due

to early compression, but although this would be an advantage to the new engine, if the opinion were well founded, the inventor, Professor Stumph, has clearly demonstrated that early compression is a source of loss. When the invention was first announced extravagant claims were made as to the economy of the una-flow engine, but it is now only claimed that this is equal to that of a good compound or triple-expansion engine, and experience of actual working on a considerable scale is offered as evidence in support of this claim. Even in this more limited sense the una-flow engine is clearly a strong rival of the ordinary engine type.

The influence of the una-flow principle in various directions can now be briefly referred to, leaving thermal considerations aside. It follows, as the complete expansion takes place in one cylinder instead of the two of the compound engine, that the una-flow cylinder should have practically the same capacity as the low pressure of the compound engine, and that since it carries the full steam pressure the loads on the piston rod and the moving parts are very much higher than for a compound engine. But in practice it has been found advantageous to reduce the una-flow cylinder 10 or 12 per cent. below that of the compound low-pressure one. This must necessarily lead to some loss of the work of the expanding steam; bearing in mind the two cylinders of a compound engine, the load on the moving line of a una-flow engine is about twice that of a compound engine. It is claimed, nevertheless, that the first cost is smaller for the una-flow, and it is obvious that it occupies less floor space; it should therefore deserve the close attention of marine engineers. A minor economy resulting from the invention is the smaller quantity of cylinder oil required, due to the abolition of one cylinder. The new type was first tried as a stationary engine for ordinary duties, but more recently the scope of its application has been enlarged and it has been applied to locomotives, as a winding engine, for driving continuous-running and reversing rolling mills, *for propelling ships,* as a portable engine and for other purposes. It may be urged that to a considerable extent it is as yet in an experimental stage for these special duties, and that the balance of advantages and disadvantages has not been fully worked out yet. As in all other inventions, time and experience are the only reliable tests. Owing to the single-cylinder construction it is clear that the normal cut-off is very early; this is obviously a disadvantage in a reversing engine, such as a locomotive, winding engine, marine engine or reversing rolling-mill engine, especially the last two. To meet this objection several devices for auxiliary inlet valves have been put forward and several of them have been tried. Another rather obvious objection in some cases is the high compression, and here, too, special relief devices are put forward. That the objections are not fatal, the examples of engines applied to these special duties by several Continental engineering firms of the highest possible standing is in itself sufficient evidence.

It is, of course, not desirable to be over-sanguine about the permanent success of this invention; the practical application of the principle is quite recent. In several directions it is only partially developed and in no direction are all the advantages on its side. Therefore whilst admitting its success, it would be unwise to suggest that in the near future all steam engines will be designed on the una-flow system. The invention and the striking commercial success which it has already achieved in a very brief period is a revelation of the results which can be obtained by the application of scientific logic to practical design.

Practical use of the new type of engine has demonstrated a most interesting fact, that although quite capable of utilizing superheated steam efficiently, the una-flow engine is about as economical when using dry saturated as when using superheated steam, lubricating and all other

charges being taken into account. This perhaps should have been anticipated, because in the una-flow engine initial condensation in the cylinder is reduced to a minimum, this being one of the two principal functions of superheated steam in the ordinary engine. It is notable that the compression steam becomes quite highly superheated, and hence its effect on the metal of the cylinder in no way tends to destroy the advantages of the correspondence between steam and metal temperatures which exist during admission and expansion.—" The American Marine Engineer."

INSTALLATION AND CARE OF STORAGE BATTERIES.

By H. M. Nichols.

Nearly every electric-generating plant, from the modest installation used for lighting summer residences to the large central stations, has its equipment of storage batteries. Sometimes the batteries are intended to help carry the peak load; sometimes their function is to furnish power during certain periods of the day when the demand for current is light; or they may be the chief dependence for current, as in the case of private lighting plants, where the dynamo is run a few hours each day to charge the battery, which is then called upon to furnish all the current used during the evening. But no matter under which one of these heads the battery falls, it is frequently placed in some dark, inaccessible and ill-ventilated corner, and the care it receives is of the most perfunctory kind.

It is not surprising under these conditions that the battery soon begins to give trouble and plays out in a few years, entailing a heavy expense for the replacement of plates, etc. On the other hand, if the battery is properly installed and is given the proper care the depreciation can be rendered very small.

The present discussion will first consider the layout and installation of storage batteries, then the operation and maintenance will be taken up.

The battery room should always be separated from the rest of the plant, as the acid fumes are very destructive to the generating machinery, their action on the insulation of generators and wiring being particularly destructive. The fumes also corrode the switchboard connections, cable sheaths and any other exposed parts. Moreover, the fumes if breathed are poisonous and are likely to cause a very disagreeable cough. The battery room should be located as near the main switchboard as possible, thereby reducing the cost of the connecting conductors.

The walls and floor of the room should preferably be of brick or tile. If wood is used it must be protected with several coats of acid-resisting paint. Also protect all exposed metalwork in a similar manner. The floor should pitch toward a central point, having a drain connected with the sewer through a lead trap.

The room should be well lighted and ventilated, and the window panes must be either ground glass or painted glass in order to keep the direct rays of the sun from striking the battery. If the sun's rays fall directly on the battery, it will cause loss of charge by local action, and also cause the electrolyte to evaporate quickly.

In the case of large installations where lead-lined tanks are used in place of glass jars, the sun's rays are not so objectionable, provided they are not directed into the top of the tanks.

In large installations exhaust fans are often provided for carrying off the acid fumes. The battery room should be so designed that the battery will not be exposed to either extreme heat or cold, and consequently it will be necessary to provide some means for heating in cold weather.

In small installations where it is not possible to have a separate room

for the battery it should be housed on shelves placed against one of the walls of the generating room. These shelves should be entirely encased with close-fitting matched boards so as to form an air-tight closet. The front should be provided with large tight-fitting doors, which when opened expose the entire battery. The acid fumes are carried off to the outside through a wooden or fiber conduit. The entire inner surface of the battery closet and all exposed ironwork should be given several coats of asphaltum or other acid-proof paint. In cold localities the ventilating duct must be provided with a wooden damper which can be kept closed in cold weather except when the battery is being charged.

SETTING UP AND CONNECTING THE CELLS.

The cells are sometimes supported by shelving along the walls, or more often by benches that rest on the floor. The shelving and benches should be shellacked and then coated with paraffin to protect them from the unavoidable acid drip and spray. Or they may be covered with asphaltum or other acid-resisting paint. In the case of large installations the tanks are sometimes set directly on the floor. In any instance the cells must be easily accessible for inspection and the replacement of plates. There should be sufficient headroom to take out the plates without removing the cells.

Care must be taken to insulate the cells from the ground, as a frequent cause of trouble is due to leakage of the current over the surface of the cells and the supports to the ground. The acid fumes keep the surfaces of the cells and supports sufficiently moist to render them good conductors. Because of this danger from current leakage it is necessary to set the cells on glass or porcelain insulators. The best plan is to stand each individual cell on four insulators of the common petticoat type, since the method will prevent current leakage between the individual cells as well as between the cells and the ground.

Sometimes a double system of insulators is used. In small installations, however, where it is not desired to go to the expense of supporting each cell separately the benches on which the cells set can be insulated from the ground instead. Lead-lined tanks are usually set directly on the insulators, but sometimes glass cells are set on wooden trays that rest on the insulators. The trays are filled with sand to equalize the strain and absorb the acid drip.

The cells are usually connected in series, and great care must be taken to join the positive terminal of one to the negative terminal of the next, and so on. If a mistake is made in connecting a cell it will be ruined when the charging current is turned on. The best indication of the polarity of the plates is their color. The positive plates are a light brown when discharged and a chocolate color when charged, while the negative plates vary from a light to a dark gray.

Before placing the plates in the cells carefully examine and remove any foreign substances that may have lodged between them. See that the hard-rubber insulators are properly spaced and that the positive plates do not come in contact with the negative ones. Also inspect the jars for cracks that might allow the electrolyte to leak out. The cells should be perfectly clean and the plates should clear the bottom from one to six inches, depending upon the capacity.

If the cells are filled with electrolyte before they are permanently connected together, it is a good plan to test the polarity of each cell with a low-reading voltmeter before making the permanent connections. Or the polarity can be determined by dipping wires leading from the two terminals in dilute sulphuric acid, the one from which the most bubbles of gas arise being the negative.

In small cells the connections are made by clamping or bolting the projecting lugs together. The connections should be scraped bright

and clean and the bolts set up as tightly as possibly. Then paint with asphaltum to prevent corrosion, and cover with okonite tape. A better method is to weld or "burn" the lugs together. If the terminals are to be burned together they should first be scraped free from dirt and oxide. A convenient scraper can be made by fastening a triangular piece of sheet steel to a suitable wooden handle. For soldering flux, use ordinary tallow. Never use acid or soldering salts, as joints made with these fluxes are likely to corrode in the course of time.

The method of welding the lugs together will, of course, depend somewhat on their size and shape. A convenient method on moderate-sized cells is to butt the two connecting lugs that are to be welded together. These lugs should be chamfered off on their top edge so as to leave a V-shaped channel where they butt together. A sheet-iron trough is then bent up having a cross-section the same as that of the terminals. This trough is then slipped over the lugs from the bottom side, is held in place with a clamp and serves to keep the molten lead in place while the lugs are being burned together.

Hydrogen gas gives the best results, but if it is not obtainable, ordinary illuminating gas may be used. If hydrogen gas is used, make sure that all of the air has been expelled from the generator before attempting to light it, since if there is any air present there is danger of an explosion. The hydrogen gas is tested for the presence of air by filling a test tube with water and inverting it in a dish of water. The test tube is then filled with gas by means of a rubber tube which is connected to the hydrogen generator, the free end being pushed up into the mouth of the test tube. As the gas fills the tube it will force out the water. When the test tube has been completely filled, remove it from the basin, keeping it inverted all the time, as hydrogen is much lighter than air, and test with a lighted match. If the gas is free from air and safe to use it will burn with a steady, almost colorless flame. If there is air present, however, the gas will explode with a sharp noise when the match is applied.

The solder should be pure lead, as tin is attacked by the acid fumes. It should be melted off the sticks and allowed to flow into the V-shaped trough between the ends of the terminals. At the same time the ends of the lugs should be kept near the melting point. Great care must be taken not to entirely melt the ends of the lugs.

Another method of connecting the terminals is to wrap a strip of lead around the terminals and put a sheet-iron mold or trough outside of this and then pour in melted lead. The lead strips must be scraped clean to insure a good joint.

The wiring for the battery room should be, preferably, lead-covered cable. If this is not used there is danger of corrosion, and liability of some of this corroded copper falling into the cells, which would be very injurious.

Care should be taken not to have any iron hooks, braces or other pieces of metal project over the cells, as there is great danger of contamination by the falling of corroded material into the cells.

For convenience in inspecting the cells a small portable incandescent lamp may be provided. Special lamps are obtainable for this purpose which are flat so that they may be inserted into the electrolyte between the plates and the jar. This lamp should have sufficient rubber-insulated flexible cord to reach to all parts of the battery room.

The battery switchboard, which must be located outside the battery room, usually forms a panel of the main switchboard. It should be equipped with a voltmeter, ammeter and device for regulating the charging voltage. In installations where it is not convenient to regulate the charging voltage by varying the dynamo voltage, resistance boxes are used for that purpose. Or in large installations a motor-generator set may be used, this being the most efficient form of regulation.

It is also essential to provide both overload and reverse-current circuit breakers. In case of a heavy overload or short circuit the battery would be injured if there were no protecting devices present. In small installations inclosed fuses may be substituted for the overload circuit breaker. The function of the reverse-current circuit breaker is to prevent the battery current from flowing back over the charging circuit in case the generator voltage should fall below that of the battery during the charging period.

ELECTROLYTE.

Concentrated sulphuric acid (oil of vitriol) is much too strong for use in storage batteries and it is, therefore, necessary to dilute it with water in the ratio of about five parts of water to one part of acid.

Commercial sulphuric acid will not do for battery work as it contains many impurities, such as iron, arsenic, copper, chlorine, etc. Use only chemically pure acid (symbol C.P.). The water used must be distilled, as ordinary river or well water contains injurious impurities. Both water and acid should be kept in tightly-stoppered glass carboys, to prevent the introduction of impurities. If the distilled water is stored in barrels there is danger of its absorbing organic material from the barrels. Mix the electrolyte in a large earthenware or glass receptacle. Pour the acid very slowly into the water as there is considerable heat generated. *Never pour water into the strong acid,* as there is great danger of the operator being burned with the acid which will fly in all directions. *Always pour the acid into the water.*

The proper specific gravity of the electrolyte will depend somewhat on the type of battery and the purpose for which it is to be used. In ordinary stationary installations a specific gravity of 1.200 is used, while in automobile and portable batteries the specific gravity goes as high as 1.300. The advantage of a high specific gravity is low resistance, but there is great danger of the plates being injured by sulphating if the gravity is run too high.

The mixture should be allowed to cool to 60 degrees, and then be brought to the proper specific gravity by the addition of a small quantity of acid or water as the case may require. Always see that the electrolyte is cool (60 degrees F.) before pouring into the cells, it being a good plan to carefully prepare the mixture twenty-four hours before it is wanted.

TESTS FOR IMPURITIES IN ELECTROLYTE.

It is very important that the acid for making the electrolyte be chemically pure and it is recommended that each carboy of acid be tested for impurities. It is also a good plan to test the electrolyte in the cells once a month, as it may have been contaminated by the corrosion of iron fittings near the cells.

Copper salts also find their way into the cells in a similar manner. Nitric acid and chlorine may be present in the new plates in small quantities.

In case any impurities are found in the electrolyte it should be drawn off, the cells and plates washed out with pure water and fresh electrolyte added.

Test for Hyrochloric Acid (Chlorine).—To a small quantity of the diluted electrolyte add a few drops of nitric acid (HNO_3) and then add two or three drops of silver nitrate ($AgNO_3$). The formation of a white cloudy precipitate indicates the presence of chlorine in some form.

Test for Nitric Acid.—A very sensitive test for nitric acid, is to mix a solution of diphenylamine ($NH(C_6H_5)_2$) in concentrated sulphuric acid (H_2SO_4) and add it to the sample under test, the presence of nitric acid will be indicated by a blue color.

Test for Iron.—Fill a test tube with the diluted electrolyte and heat it to the boiling point, add several drops of concentrated nitric acid (HNO_3) and boil again. Repeat this operation two or three times. When the solution is cold add a few drops of potassium-sulphocyanide (KCNS) which will color the solution a deep red if there is any iron present.

Test for Copper.—To a diluted solution of the electrolyte add ammonium hydrate (NH_4OH or common ammonia) until the resultant mixture gives an alkaline reaction. A deep-blue color indicates the presence of copper.

Test for Arsenic.—To a diluted solution of the electrolyte add an equal portion of hydrogen-sulphide solution (H_2S). A yellow precipitate indicates the presence of arsenic.

If the electrolyte has been previously used in batteries there is likely to be a black precipitate, due to the presence of lead, and often the commercial acid contains a little lead which does no harm. In making the foregoing tests, it should be kept in mind that the reagents used must necessarily be pure or the results obtained will be unreliable. Use only those reagents that are labeled chemically pure.

FIRST CHARGE.

The charging current should be ready to turn on as soon as the electrolyte is poured into the cells; otherwise the plates are liable to be injured by sulphating if allowed to stand in the acid without being charged. Have all connections made, cables run, etc., to avoid delay, and never under any circumstances allow the new plates to stand in the acid longer than two hours before beginning the charge. Care must be taken to see that the positive pole of the charging dynamo is connected to the positive pole of the battery, as a reversal in connections would ruin the battery.

It is a good plan to test out the generator connections with a direct-current voltmeter and then make them permanent to avoid danger of their being accidentally changed. If at any time repair work is done on the generator or cables leading to the battery board, recheck the polarity, as there is always the possibility of reversal.

The first charge should be carried on for a period of 20 to 30 hours or even longer, as this charge is necessary to complete the forming of the plates. The charging may be carried on at the normal rate, provided the temperature of the cells does not go above 100 degrees F. If the temperature goes above this point the charging current must be reduced. It is permissible to charge at a rate lower than normal for a correspondingly longer time if it happens to be more convenient to do so.

The normal rate of charge is usually marked on the cells by the manufacturers, but it may be found by dividing the ampère-hour rating by eight. Thus for a cell the rated capacity of which is 800 ampère hours, the normal charging rate would be 100 ampères.

The voltage required at the beginning of the charge will be about two volts per cell, and this will rise to a maximum of about 2.6 volts when the cells are fully charged. As the charging nears completion the cells will begin to gas freely, indicating that the plates have taken up nearly all the charge possible and that the surplus current is being used up in decomposing the electrolyte. At this point it is well to decrease the charging current, although moderate gassing does no particular harm other than waste energy.

When the cells are first filled with electrolyte the specific gravity will fall considerably below 1.200, due to absorption by the plates. The specific gravity will rise during the charge until it reaches slightly over 1.200 at full charge. During the ordinary operation of the cells the specific gravity when charged is about 0.025 higher than when discharged.

GENERAL CHARGING.

Always charge at the normal rate or lower except in the case of emergencies. The longest life and highest efficiency is obtained when the battery is charged slowly. During the charge the voltage rises from about 1.8 volts per cell to approximately 2.5 volts when fully charged.

As the battery becomes fully charged bubbles of gas will be given off freely, which will give the electrolyte the appearance of boiling. Sometimes these bubbles are so fine and numerous that they give the liquid a milky-white appearance. When the battery reaches this stage it is considered fully charged, although it can be made to take up a small additional charge by reducing the strength of the charging current.

The specific gravity of the electrolyte gives another valuable indication of the amount of charge held in the cell, but it is usual practice to depend principally on the voltmeter readings.

If the battery is allowed to remain idle for any length of time, it should be given a charge every week or two to compensate for the loss of charge due to current leakage. If the battery is allowed to stand much longer than two weeks without being freshly charged, there is great danger that the plates will be injured by sulphating.

Trouble is sometimes experienced from excessive acid spray. As the battery becomes nearly charged the gas bubbles become so numerous that the electrolyte appears to boil, and these bubbles breaking at the surface throw a fine spray of acid into the air. This spray corrodes all the metal fittings that it comes in contact with and is also very irritating to breath.

Various remedies have been tried, such as having a film of oil over the electrolyte which does away with the spray, but is objectionable because it sticks to the plates when they are removed, increasing their resistance when they are replaced. Another plan is to put glass covers over the tops of the cells, but they soon collect dust which forms a conducting surface for the leakage of current. The best plan is to reduce the charging current near the end of the charge and depend on good ventilation to remove what fumes are given off.

DISCHARGING.

In ordinary practice a battery is discharged within a few hours after it has been charged. Under these conditions the battery will deliver from 75 to 80 per cent. of the energy put in during charge. In some installations the battery is kept "floating" on the line so that it will take care of any heavy overloads and thus keep the line voltage from fluctuating. In this type of installation the battery carries a considerable percentage of full charge most of the time, as it is likely to be on discharge for only a few minutes at a time and then shift to charge as the load drops, and so on throughout the day.

If the battery is allowed to stand a week before discharging there will be an additional loss of about 25 per cent. in efficiency.

The discharge rate in ampères is usually the same as the charging rate, which is found by dividing the ampère-hour rating by 8. The battery may be discharged at a rate considerably greater than the 8-hour rate for a correspondingly shorter time. In doing this, however, a certain percentage of the capacity in ampère-hours is wasted. For example, a cell whose 8-hour discharge rate is 50 ampères, may be discharged at the rate of 200 ampères for one hour, but in doing this the cell suffers a loss of 50 per cent. in its ampère-hour capacity. Excessive discharge rates are injurious to most forms of cells and should be avoided.

The types of cells that use pasted plates are the most liable to injury from this cause. A battery should never be discharged below a voltage of 1.8 volts per cell, except in the case of heavy discharge for short

periods. If the battery is discharged at the one-hour rate, the voltage may be allowed to fall as low as 1.6 volts per cell. If this rule is not observed the cell is very likely to be permanently injured.

Never allow the battery to stand discharged for more than two or three days, as, otherwise, its capacity is likely to be considerably lessened by "sulphating."

WEEKLY INSPECTION.

Once a week each cell in the battery should be carefully inspected and tested. With the battery fully charged, measure the voltage of each cell with a low-reading voltmeter. For this purpose a pair of prick-point leads will be found convenient. These are made by soldering a length of flexible cable to a sharp spike which is driven into a wooden handle, the cable being brought out through a hole drilled through the central axis of the handle.

With the battery fully charged also measure the specific gravity of the electrolyte in each cell. In measuring the specific gravity of the electrolyte use a battery syringe to draw a sample for test from the lower part of the cell, as there is likely to be a slight difference in density between the top and the bottom of the cell. A low specific gravity or low voltage indicates trouble of some kind which should be investigated and corrected at once. If any of the positive plates have a light color it indicates insufficient charge.

Examine the cells for short circuits, both external and internal. When sufficient sediment collects in the bottom of the cells to threaten a short circuit, siphon off the electrolyte, which may be used again, and flush out the cells with clean water.

The electrolyte should be kept at least ½ inch above the tops of the plates. Any electrolyte that is spilled or dissipated by acid spray should be replaced by electrolyte of 1.200 specific gravity. Any loss due to evaporation must be replaced by distilled water. When the cell is fully charged the specific gravity should be about 1.200. If the hydrometer shows a lower figure when the voltage of the cell and the color of the positive plates indicate full charge, dilute acid should be added to bring up the specific gravity to 1.200. Never add strong acid directly to the electrolyte in the cell.

If the specific gravity is too high add pure distilled water to the bottom of the cell with a battery syringe or rubber tube. It is necessary to add the water at the bottom, as it is lighter than the electrolyte, and if it was added at the top it would not mix well.

A record should be kept of the weekly inspection of the battery so that a comparison can be made from week to week of the action of each individual cell.

A convenient form for this record is given below.

STORAGE BATTERY INSPECTION RECORD

Station———————Date———————

Cell No.	Volts Open Circuit	Specific Gravity	Remarks

Always take the record with the battery fully charged and also record the total battery voltage. Under the column headed "remarks," note any peculiar conditions of the cell and also any troubles corrected. Also record any additions of water or acid to the electrolyte to bring its specific gravity to the proper value.

LOCATING AND CORRECTING TROUBLES.

The most frequent troubles that occur in storage batteries are short circuiting, sulphating, flaking, disintegrating of the plates, and buckling or warping of the plates.

SHORT CIRCUITING.

A short circuit is indicated when the voltage and specific gravity are below normal. The short circuit may be caused by sediment collecting in the bottom of the cell or by some foreign substance falling into the cell. Cracked insulation may also cause a partial short circuit.

A cell that has been short circuited will require more than its usual amount of charge for some little time. This can be accomplished by charging the cell as usual but cutting it out of circuit for several discharges. This method is only practical with small cells that are connected together with bolt connectors. Another plan that does not require the disconnecting of the cell under treatment is to give it an additional charge from an outside source after the battery has been fully charged. Temporary leads can be run to the defective cell for this purpose.

SULPHATING.

A cell is said to be sulphated when a whitish scale of lead sulphate forms on the plates. This scale is a non-conductor and thus serves to insulate the active material from the plates. Any indications of sulphating should be corrected at once, for if it is allowed to continue it will not only greatly reduce the capacity of the battery but will also lead to other serious troubles.

Sulphating may be caused by overdischarging, or the battery may be left in a discharged condition for several days, even if the limit of discharge has not been exceeded. If the electrolyte is allowed to get too hot (due to an excessive discharge rate) or if it is too strong the plates are likely to sulphate. A short circuit may also cause sulphating by discharging the cell below its proper voltage.

A cell that is badly sulphated should have the plates removed and carefully scraped until all traces of the scale have been removed. The cell should then be charged at a low rate (from one-quarter to one-half the normal rate) and only partially discharged. This treatment should be continued until the sulphating is entirely eliminated and the cell returns to its normal condition.

In some instances it is a good plan to add a small quantity of sodium carbonate to the electrolyte, which will help to dissolve the objectionable scale. After the scale has been removed the electrolyte should be thrown out, and the plates carefully washed to remove all traces of the soda.

FLAKING, DISINTEGRATING AND BUCKLING OF THE PLATES.

If the plates are allowed to become badly sulphated the final result will be that the active material will peel off in large flakes. Buckling is caused by sulphate working in between the active material and the supporting grid. Flaking and buckling are also caused by excessive discharge rates and sometimes by long continued overcharge.

Flaking is objectionable because it reduces the capacity of the cell, due to the loss of active material. Buckling is likely to break up the pellets of active material and cause them to drop out.

Sometimes a plate that has begun to buckle can be straightened by putting it between two soft pine boards and pounding on them gently with a wooden mallet, taking care not to disturb the active material. Positive plates are more likely to be injured from any of these troubles, and it is to them that particular attention should be given.

TAKING THE BATTERY OUT OF SERVICE.

In many installations, such as country residences, summer hotels, etc., the storage battery is allowed to lie idle for a period of several months. In installations of this type the storage battery should be taken out of service at the end of the season.

This is accomplished by first discharging the battery fully at the normal rate, then siphoning the electrolyte into clean carboys for future use, and filling each cell as soon as it is emptied with pure water. When the electrolyte has been replaced with water in all the cells, the battery should be discharged until the voltage falls below one volt per cell with normal current flowing. When this condition is reached the water should be siphoned off. The plates may be left in the cells or they may be removed and packed away for storage. When it is desired to put the battery in service again, proceed as when the battery was first started, giving it an initial charge of from 20 to 30 hours at the normal rate.—"Power."

THE CORROSION OF LEAD.

By Richard H. Gaines, Chemist, Board of Water Supply, New York.

The problem to determine what particular metal or combination of metals is best suited for a given purpose in engineering construction is sometimes one of great difficulty. A mistake in judgment may be at the expense of economy or durability or may even lead to a disaster. The decision of the engineer, to be correct, must be based on a thorough knowledge of the physical properties of the metals under consideration, and this is generally gained by experience.

In many constructions the choice of some of the materials is determined more by their durability under conditions of working than by their strength or other properties, a more expensive and weaker material being often chosen in preference to a cheaper and stronger one on account of superior resistance to corrosion. Examples of this are afforded by the frequent use of special bronzes in places where, except for their durability, the stronger and cheaper iron and steel would be preferable.

Incidental to a recent study to aid in determining whether it would be safe to substitute lead-lined steel pipe for bronze pipe where a material of great durability was required in portions of a water conduit, some experiments were made and facts were collected from the experience of others bearing on the corrosion of lead. From the data obtained it was concluded that for the particular purpose in view the relative merits of bronze pipe and lead-lined steel pipe would hardly admit of comparison. Under whatever conditions lead withstands the action of water or acids, the bronzes are similarly unaffected, while under other conditions of service in which the bronzes are practically untouched by corrosive action lead would be destroyed. Lead-lined steel pipes no doubt have their uses in the chemical manufactures, and may also find extensive application for the conveyance of hard waters, or acid waters of a certain character in mines, but they cannot be recommended for use in connection with city water supplies. Owing to its peculiar physical and chemical properties, lead affords a doubtful protection to iron or steel

conduits from corrosion, and under some conditions might prove an absolute disadvantage, if not an actual menace, to the life of the pipe.

THE ACTION OF ALKALIES.

A peculiarity of lead is that it may be corroded either by alkalies or acids. Thus, lime mortar, lime putty and lime water will attack lead; if the mortar is very alkaline, the effect will be greater. Proof of this was established by experiment as well as from observation of lead service pipes in wet concrete.

The following experiment was made to test the effect of an alkaline seepage water on lead: A weighed sample of lead was immersed for a period of eight days in seepage water that leaked through the concrete walls of a tunnel. The sample was taken out daily, washed, dried and weighed, and the loss in weight noted. At the end of the test period it was found that progressive corrosive action had taken place, amounting to 0.132 per cent. in eight days, or at the rate of about 6 per cent. a year.

Several examples of corrosion of lead service pipes in wet concrete were observed, one of which will suffice to be mentioned here. In a bathing establishment in Brooklyn two lead pipes passed up through a concrete floor—one of the pipes was for hot water and the other for cold water. Owing to the free use of water on the floor the concrete was wet much of the time. Here the lead pipe for the conveyance of hot water was nearly destroyed by corrosion in five years, while the cold-water pipe was also deeply corroded. No evidence was found of leaking electric currents in the building to aggravate this action.

CORROSION IN CONCRETE.

A series of experiments was made to determine what loss lead suffers from corrosion as compared with steel and some other metals when embedded alone or in contact in very damp concrete.

Specimens of the following metals were weighed and embedded singly and in contact in damp concrete and allowed to remain therein for two months. At the end of the test period the concrete blocks were broken up and the metals taken out, carefully cleaned, dried and reweighed, the loss in weight representing the amount of corrosive action in each specimen.

Single Specimens.

	Grams		Grams	Loss
Metal:	Wt., Jan. 2, 1912	Wt., Mar. 4, 1192	Loss 2 mo.	Grams sq. ft.
Manganese bronze	73.6655	73.6475	.0180	.32
Steel	39.1556	39.1481	.0075	.135
Lead	92.3806	91.7146	.6660	11.99
Copper	73.7630	73.7272	.0358	.64
Monel metal	62.9667	62.9646	.0021	.04
Metals in contact:				
Steel	37.0380	37.0270	.0110	.20
Manganese bronze	70.6864	70.6700	.0164	.30
Steel	38.1746	38.1700	.0046	.08
Lead	90.0399	89.5408	.4991	9.08
Steel	38.8055	38.8031	.0014	.03
Copper	70.1913	70.1348	.0565	1.04
Steel	38.6396	38.6271	.0125	.23
Monel metal	60.1092	60.1074	.0018	.03
Steel	34.5625	34.4626	.0999	2.48
Lead	83.8596	83.5163	.3433	6.77
Copper	68.9752	68.9626	.0126	.31
Steel	34.8702	34.8026	.0676	1.68
Fiber	.....	.....	....	...
Copper	64.1247	64.1122	.0125	.31

The resulting losses show but slight differences when in contact and alone, and therefore give no evidence of electrolytic action when the metals are coupled in concrete. With the exception of the lead, the corrosion loss of all the metals was small, that of the monel metal almost nil.

The action of the lead confirms results obtained from actual experience and shows that this metal may suffer very appreciably in an alkaline as well as acid medium. The corrosive action in this case was observed to be solvent in character, no protective coating being formed to hinder further change.

Sir William Crooks once said that lead was the first cousin of thallium, which Lothar Meyer called the ornithorhyncus of the metals. This strange Jurassic animal possessed the body of mammal and the beak of a bird. Whether such a doubtful order of relationship in the family of elements is true or not, it is a fact that the chemical properties of lead are very peculiar, and they present some remarkable contrasts. While lead resists the action of sulphuric and hydrochloric acids in a far higher degree than iron, zinc or tin, it is readily attacked by weak organic acids and is slowly dissolved even by pure water containing air.

With respect to corrosion the behavior of lead is decidedly inconsistent. Notwithstanding that lead is very slightly acted on by some of the strong mineral acids in the cold, it is soon extensively corroded when exposed to the action of moist air in the presence of carbonic acid and eventually becomes converted into a mass of white lead. Since carbonic acid is produced abundantly in the decay of animal and vegetable matter, metallic lead is much affected when kept in contact with such substances in the presence of air, the oxygen of which unites with lead to form an oxide which then combines with carbonic acid. The oldest process for the manufacture of white lead depends upon the corrosion of the lead by contact with decaying organic matter in this manner. Bloxam, in his work "Metals and Their Properties," makes this statement: "In breach-loading cartridges where grease is employed as a lubricator the bullets have sometimes become partly converted into white lead and thus increased so much in bulk as to burst open the copper case of the cartridge and render it useless."

THE CORROSION OF LEAD IN THE SOIL.

The impression prevails among many engineers that in the absence of stray currents the corrosion of lead in the soil is negligible. This is not always true. The facts are that while in some soils lead is very slowly affected by corrosion, in others an active chemical change or deterioration of one kind or another takes place. For example, "the lead of old coffins is sometimes found to have become almost entirely converted into an earthy looking mass of basic carbonate of lead" (Bloxam, "Properties of Metals").

The Russian engineer A. N. Schensnovitsch, of Odessa recently sent by his government to New York to examine our pier and dock system, told the writer of an interesting case with which he was familiar of the destruction of lead water pipes by corrosion that occurred in St. Petersburg during the '70s, before the days of industrial electricity or other conditions that could give rise to electrolysis. According to this engineer, in 1860–61, or thereabouts, a quarter of the City of St. Petersburg was served with water by a system of lead mains. In from ten to fifteen years these pipes had become so pitted by corrosion as to necessitate extensive changes. The cause of the trouble was attributed at the time to some local peculiarity of the soil, the exact nature of which was never ascertained. Mr. Schensnovitsch stated that the whole system was subsequently replaced by cast-iron pipes, which had proved durable and satisfactory. The superintendent of the waterworks of a suburban town in the vicinity of New York City told the writer that

several years ago he had occasion to renew a number of lead service pipes on account of deterioration from corrosion. As he expressed it, "The pipes were pretty well used up, presenting the appearance of just having passed through a severe attack of smallpox. The lead, moreover, had the appearance of having lost all its vitality. There was no indication of electrolysis playing any part here."

In several cases reported by recent engineering periodicals accounts are given of the lead pipe in the earth "losing its vitality, becoming brittle and porous, rendering renewal necessary after a comparatively short period of service, or the substitution of some other kind of pipe." Cases are also reported where it was deemed necessary to lay the lead pipe in wooden troughs, to surround it with pitch, or to otherwise protect it from the corrosive influences of the soil.

THE CORROSION OF LEAD IN WATER.

So far as ordinary atmospheric corrosion is concerned, lead is one of the most durable of the common metals, undergoing no change in dry air or in water perfectly free from air. It is, moreover, only slightly affected by hard waters or dilute solutions of either hydrochloric or sulphuric acids. The latter acids quickly form coatings on the surface of the metal, which protect it from further action. Lead, however, is readily dissolved by water high in nitrates and by dilute nitric acid. It is also more or less rapidly corroded by weak organic acids in contact with moist air. Certain waters which actively corrode lead are those with a slightly acid reaction from peaty swamps. There are certain microbes associated with peat which are acid producing, and which impart acidity to waters which have been in contact with peat.

Soft waters are particularly unsuited for conveyance in lead pipes, and in such waters containing nitrates derived from decaying vegetation the amount of lead dissolved is large. Every plumber knows that pure soft water will attack, and sometimes destroy, lead pipes. For this reason it has often been found necessary to line lead pipes with tin.

When lead pipes are acted on by water the corrosion is more or less irregular, some portions being hardly attacked, while in other parts holes may be eaten through. This does not seem to be due to any irregularity in the metal but merely to accidental circumstances. One authority quotes various experiments to show that lead water pipes should be kept full of water all the time to prevent deterioration.

The corrosion of lead by pure aërated water takes place as follows:

Lead (Pb) + Dissolved Oxygen (O) = Lead Oxide (PbO);
PbO + Water (H_2O) = Lead Hydroxide (PbO_2H_2).

If exposed to the action of clean, soft water containing the normal quantity of dissolved oxygen, the lead is oxidized to hydroxide, which dissolves. After a time this is converted, by the action of the atmospheric carbon dioxide, into the basic carbonate of lead, $2PbCO_3$ and $Pb(HO)_2$. Lead hydroxide is then again formed, and thus the corrosive action may be continued.

Potable waters always contain a certain amount of salts in solution, and the corrosive action depends to some extent upon the nature and quantity of the salts present. The waters which act least on lead are those containing carbonate of lime, phosphate of lime, and, in a less degree, sulphate of lime. The waters which are most liable to act upon lead are those obtained from upland gathering grounds, waters which are soft and usually of remarkable purity. When highly oxygenated the latter form no protective coating against solvent action. On account of the quantity that may be thus dissolved lead has always been considered a more or less dangerous metal in connection with water supply

for drinking purposes. Acting as a cumulative poison, its salts produce serious results if taken into the system, even in very minute quantities. for any length of time. Although indirectly related to the subject of corrosion, the experience of certain of the towns of Lancashire and Yorkshire in England should never be forgotten where the use of lead water pipes is under consideration. In these towns lead poisoning was prevalent for a considerable period, doing immense damage to the health of the inhabitants before its real nature was recognized and its cause discovered. Incidentally, it may be said that the compounds of lead are poisonous practically in proportion to their solubility. Thus the metal itself and its sulphide, being incapable of absorption as such into the system, are practically innocuous, while the soluble salts—nitrate, chloride and acetate—are active irritant poisons. The oxide, sulphate and carbonate are much less active, but continued exposure to lead fumes or to any atmosphere in which these substances are present in the form of dust brings on first "lead colic" and later, if exposure to the dust or fume is continued, a more chronic form of poisoning called "lead palsy," accompanied by great emaciation.

THE CORROSION OF LEAD BY ELECTROLYSIS.

Instances are commonly reported of the electrolysis of lead pipes. In some of these cases, such as have occurred at St. Paul, Omaha, and Paterson, N. J., all the phenomena of electrolysis were no doubt present. In others damage from stray currents has by no means been proved, while the observed phenomena rather suggest ordinary chemical corrosion. In several cases of lead-pipe deterioration, called electrolysis, it was found that molecular changes of another character had taken place in the metal, similar to what Milton and Larke (Proc. Inst. C. E.) described as decay.

The electrolysis of either lead or lead-lined steel pipe, however, is a very real trouble, and the interest attaching to it here is the ease with which it may occur and the rapidity with which serious damage may be done. A few years ago the Westinghouse Electric Company showed by experiments at Pittsburgh how readily buried lead pipe could be corroded by electrolysis. This company also made a series of tests in different soils to compare the corrosive action of stray currents on embedded lead and steel pipes. It was demonstrated that in some soils lead pipe was even more rapidly destroyed by electrolysis than steel. This accords with actual experience reported from several cities. At St. Paul, where considerable damage to lead water pipe occurred, presumably from electrolysis due to escaping current from electric railway lines, cast-iron pipe in the path of the same currents is said to have been little affected by corrosion. In New York City an engineer connected with the water department told the writer that in the few instances in which there had been any trouble from electrolysis of water pipe in Manhattan, "the lead joints were the first to go."—"Engineering Record."

TEMPERATURE TESTS ON JOURNAL BEARINGS.

By Allan M. Bennett.

SYNOPSIS—Comparative tests showing the temperature rise with ball-seated bearings of different metals under both forced lubrication and ring feed. The results of a test on a concentric-sleeve bearing are also included.

The curves here given are from the results of tests made by the writer for the purpose of determining the relative value of bearings of various designs and compositions, for high-speed duty, such as that met with in steam turbines, and their connected apparatus. It was decided

that the tests should show, with temperature rise as a basis, the following specific comparisons:

First, that between bearings supplied with oil by ordinary ring feed and those in which forced lubrication was used; second, a comparison of results from the use of different materials under like conditions of lubrication, and, third, a comparison of the straight-seated and self-aligning types. In addition, from the last two series, was to be observed the effect on vibration of the various materials and methods of mounting.

The tests were made on journal-type bearings fitted to an ordinary direct-current motor, and all were run under the same conditions of load, bearing pressure and speed. In each case the run was continued until a constant temperature had been reached. The motor was run free, as it was thought that the resultant pressure on the bearings, due to the weight of the armature, load and varying tightness of belt would be difficult to accurately determine for each case. Besides, the condition of running free, so far as the bearings were concerned, more nearly approached that found in turbine sets, where the driving and driven machines are usually in line with each other, either coupled or on the same shaft.

The self-aligning bearings were all of the ordinary ball-seated type with one exception, that being composed of three concentric sleeves with oil clearances between them, the outer sleeve being doweled in the bracket, while the inner sleeves were free to rotate and accommodate themselves to irregularities of construction and alignment.

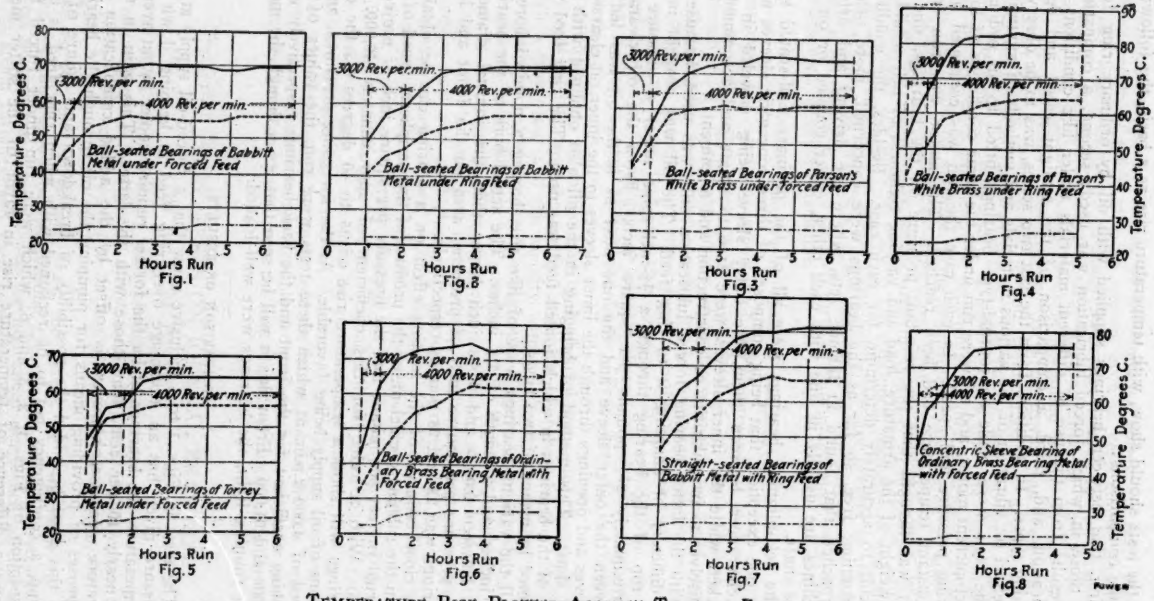
With the latter bearing forced lubrication only was used, because of the difficulty of adapting it to ring feed. The oil was brought in at the top of the bearing through a ⅜-inch pipe under a pressure of approximately 2½ pounds per square inch. From the oil clearance between the outer sleeve and the one next to it the oil was led by grooves and openings through the inner sleeves to the inner oil clearances and shaft. This method of bringing in the oil also obtained with the rest of the bearings in which forced feed was used. The ring feed was effected by means of two rings.

All the various bearings were of like size, having a nominal bore of 1¾ inches, and a length of 5¼ inches. The actual bore of the bearings was between 0.0025 and 0.003 inch larger than the journal diameter. The pressure per square inch of projected area on the front and back bearings was 23 and 28 pounds respectively.

A close estimate of the heating effect on a bearing can be obtained from the rubbing coefficient, or the product of the peripheral speed of the journal in feet per minute and the pressure per square inch of projected area. With a value for this coefficient of approximately 40,000, the bearings will show a temperature rise of 35 to 40 degrees C., the conditions of oil supply being favorable. At the foregoing pressures, and a speed of 4,000 r.p.m. at which these tests were run, the values of the rubbing coefficient for the front and the back bearings respectively were 42,000 and 51,000. From this it will be seen that, even though the motor was running light, the bearings were well loaded.

COMPARISON OF RESULTS.

The tests in Figs. 1 to 4 inclusive show that a forced-oil supply at the pressure given has an advantage over ring feed in keeping down the temperature, the bearings under the former running cooler by an average of nearly 10 per cent. than those with the latter. This gain in temperature decrease, however, is offset by the added complication and expenses of providing means for pumping the oil through the bearings. To this must be added the possibility of breakdown and failure of the pump, a contingency not to be reckoned with when ring feed is used. Inspection of Figs. 1, 3, 5 and 6, which were run under forced feed, shows a difference of temperature rise in favor of the softer metals.


Temperature Degrees C.
3000 Rev. per min.
4000 Rev. per min.
Ball-seated Bearings of Babbitt Metal under Forced Feed
Hours Run
Fig. 1
Ball-seated Bearings of Babbitt Metal under Ring Feed
Fig. 8
Ball-seated Bearings of Parson's White Brass under Forced Feed
Fig. 3
Ball-seated Bearings of Parson's White Brass under Ring Feed
Fig. 4
Ball-seated Bearings of Torrey Metal under Forced Feed
Fig. 5
Ball-seated Bearings of Ordinary Brass Bearing Metal with Forced Feed
Fig. 6
Straight-seated Bearings of Babbitt Metal with Ring Feed
Fig. 7
Concentric Sleeve Bearing of Ordinary Brass Bearing Metal with Forced Feed
Fig. 8

TEMPERATURE RISE PLOTTED AGAINST TIME OF RUNNING.

The tests in Figs. 2 and 4, in which ring feed was used, also show this same result.

Between the ball-seated and straight-seated bearings, the choice lies with the former. In Figs. 2 and 7, which show a comparison of these types, there is a difference of 8 degrees, or 16 per cent., in the case of the back bearings, and 7 degrees, or 20 per cent., between the front bearings.

The curve in Fig. 8, for the concentric-sleeve bearings, is plotted from an average of two runs on the same bearing. So far as temperature rise is concerned, this does not offer any advantage over the bearings of ordinary construction, the temperature rise being practically as high as that of some of the other bearings with ring feed. With this bearing, however, the vibration of the machine was very perceptibly lessened, and it is probable that the increase in temperature can be accounted for by this fact, the vibration being absorbed in the bearing and manifested in heat.

With the straight-seated bearings, Fig. 7, the vibration was much more noticeable than with any of the self-aligning bearings. Of the latter, the babbitt-metal bearings appeared to have a greater effect in reducing vibration than those of the harder metals.—"Power."

CARE OF MAGNETOS.

By A. L. Brennan, Jr.

Magnetos can be divided into two classes—low-tension and high-tension, but there are certain rules that apply equally to both types. These have to do with keeping the machine free from water, oil and other foreign matter.

Magnetos invariably revolve at high speeds, and consequently, if the bearings are not supplied with a suitable lubricant, wear will result. This wear takes place where there is the most lateral pressure which results in the bearings being worn slightly out of line and thus the armature will not revolve upon a true center. On the other hand, over-lubrication is also detrimental, inasmuch as the oil has a tendency to creep. About the best way is to resort to frequent oiling, using small amounts, say, two drops each time.

Nearly all magnetos now have permanent magnets and, therefore, an operator is seldom confronted with an inoperative magneto, due to loss of magnetism, as was quite frequently the case a few years ago. Present-day troubles are invariably attributed to faulty connections or contacts, poor adjustments, or to accumulations of oil or dirt. Troubles with low-tension magnetos are in most cases due to the frictional surfaces of the armature becoming gummed or to faulty carbon brushes.

When a magneto gives trouble it is advisable to wash the parts affected in a tin of gasoline and then polish the surfaces with fine sandpaper. Emery cloth should never be used for this purpose, as small particles of carbon are likely to cause short-circuits or partial short-circuits, which are even more difficult to locate. Carbon brushes sometimes wear unevenly, but this is easily remedied by rubbing the brush upon a piece of flat sand-paper, care being taken to hold the carbon at right angles to its contact surface; this treatment will insure a positive contact.

With high-tension magnetos the most troublesome parts are the points in the breaker box, these having a tendency to become pitted and cause the motor to misfire. Ordinarily, the points need only to be cleaned with emery cloth, but if badly pitted they will probably need filing, and this will necessitate their removal. It is important that they be filed at such an angle that when they are in contact they will bear over their entire surface. If the points only touch on one side, for instance, the spark efficiency will be greatly reduced.

In regard to the correct gap that should exist between these points, much depends upon the magneto. However, the majority of manufacturers supply suitable open-end wrenches and gages for all necessary adjustments, and an operator cannot go wrong if he will but follow these scales.

The distributor carbons are apt to cause slight trouble by not making positive contacts, but they can be trued up easily as already mentioned. Sometimes when carbons wear considerably they do not bear with sufficient pressure to insure a positive contact, which is due to the decreased tension of the spring. This trouble is easily remedied by removing the carbon and bending out the spring.

The component parts of a spark plug should be kept tightly assembled, the points clean and about the thickness of a dime apart. Inspection of the breaker points is had by removing the cover. Some operators make a practice of cleaning out this box with gasoline, but if this is done care must be taken not to slop gasoline around, for if the motor suddenly starts the gasoline in the breaker box is likely to be set on fire.

Before removing a "set" magneto, suitable timing marks should be made, for, otherwise, trouble will be experienced when putting it back.—"Power."

LARGE-MOTOR VESSELS.*

For the shipbuilders, and for the whole shipping trade, the large-motor vessel question is by far the most momentous one of the day; its importance is as great as was that of the introduction of steam power some 100 years ago, the only difference being that technical improvements now make their way much more rapidly than they did a century ago.

Chief among the many new departures in ship propulsion which the last decade has brought us have been the water-tube boiler, the turbine and superheated steam. Of these only the last named has established itself in the merchant services, the two others being almost entirely confined to war vessels, and here and there only applied to fast passenger vessels. In contrast with these conditions the large motors will at once appeal to the merchant service, although the increase of power which they bring will be of great value to war vessels also.

The stage of development now reached is such that we must give our serious attention to the question, "Will the propulsion of sea-going ships in the near future or within a measurable time be effected wholly or for the most part by means of oil motors instead of by coal and steam?" The economical importance of this question may best be made clear by means of figures. Statistics of the total horsepower now in existence in merchant vessels do not exist, only the annual returns of individual countries in some cases giving the indicated horsepower totals of recent years along with those of the gross register tonnage. From these latter returns it appears that for every 10 gross register tons about 8 horsepower has in recent years been turned out; if a proportion of about 10 to 6 be taken for the whole of the merchant-steamer fleets of the world the engine equipments of the latter will work out at six-tenths of the 37,000,000 gross register tons given by Lloyd's Register, or in round numbers at 22,000,000 of indicated horsepower. The naval fleets of the world are credited in the various statistical compilations with indicated horsepower totaling up to 15,000,000. For the first cost of the engines of merchant steamers $36 (£7–10) per indicated horsepower may be taken as a low estimate, about $12 (£2–10) going to the shafting and to the auxiliary engines and $24 (£5) to the main engines and boilers. The corresponding values for war vessels must be placed higher, so that the

* From a paper read by Professor W. Lass at the III. German Ocean-Navigation Day (III. Deutscher Seeschiffahrtstag), Berlin.

total value of the main engines and boilers of sea-going vessels of all kinds amounts in round numbers to $975,000,000 (£200,000,000), which may within measurable time be for the most part rendered worthless by the advent of the oil motors.

A shifting of values of this revolutionary character can be brought about only by very considerable advantages attaching to the new mode of propulsion. In what, then, do the great disadvantages of the propulsion by the steam engine lie? From the point of view of the shipowner and the merchant the disadvantages are not so very great. For commercial purposes the ship is only a means to an end for the shipowner, the engine is only a necessary evil, and the less he hears of it the better he is pleased. For ocean commerce the steam engine fulfills its purpose; it has attained a high degree of reliability, and supplies of coal for it are obtainable at all important towns of the world. In general, then, the position is justified which I have found many managers of shipowning companies take up, that they are not by any means pleased at the prospect of the so-called "improvements," which, in the keen competition of the period of transition, will bring a series of very disturbing alterations in their train.

As has so often been the case in recent times the movement has been set on foot by the engineers, who are constantly striving after the economically better. The disadvantages of propulsion by the steam engine are of a general character, and lie in the complicated indirect development of power, in which large losses occur by reason of the generation of the steam in the boilers. The endeavors of the engineer, from which the motors have sprung, are directed towards the abolition of this intermediate member and the direct development of power at the point where it is required, namely, in the engine itself.

What are the advantages which thereby accrue to navigation? The abolition of the boilers will be hailed with delight not only by the sea-going and superintending engineers, but also by the captains and owners. The boilers constitute a constant source of care and danger, and require large staffs for their working, the obtainment and management of which are beset with increasing difficulties. Even in the case of an ordinary merchant steamer, the allowances of weight and space for the boilers are considerable, while in large passenger liners and war craft they increase to such an extent as to determine the sizes of the vessels or the speeds of these on given dimensions. The sole reason why the *Mauretania* had to be so much larger than the fast liners of the North German Lloyd Line was that the large horsepower necessary for the attainment of 25½ knots in place of the 23½ knots of a vessel of the size of the *Kaiser Wilhelm II* entailed an amount of boiler space which could not be obtained otherwise. In addition to the space and weight thus required comes the supply of fuel. As a result of the indirect development of power by the boilers, the average consumption of coal in the best steam installations is still at least 1.3 to 1.55 pounds per indicated horsepower per hour, that in the oil motor with its direct production of power being only about one-third as much.

The great advantages of the motor propulsion as compared with that by the steam engine are, then, the following: Great saving of space and weight in consequence of the abolition of the boilers and of the reduction of the consumption of fuel by one-third; to this comes the elimination of a large proportion of the stoker contingent. A large number of designs which, with the coöperation of the shipowners, have been got out during the last few months for some of the principal types of merchant vessels have shown favorable results.

Compared with a steamer, a motor merchant vessel in the European coasting trade saves about 10 per cent. in space and weight; in the long-voyage trades, such as those to South America and the Black Sea, the saving ranges up to 20 per cent.

A sea-going fishing vessel with a motor can take fuel with her for twice the time that a steamer can, and in addition can make room for about 50 per cent. more fish.

The most marked differences, however, are shown by fast passenger liners. A fast passenger vessel of the size of the *Kaiser Wilhelm II* can take in a motor installation of 60,000 indicated horsepower in place of the 40,000 indicated horsepower now carried, and will thereby attain a greater speed than the much larger *Mauretania;* at the same time she can take in sufficient oil in New York for the journey out and home, while under present conditions she has to coal both in Bremerhaven and in New York. Meanwhile, in spite of the 50 per cent. increase of power and the 100 per cent. increase of radius of action, a considerable saving in weight is effected and the draught is thereby reduced.

Similar results are shown by war vessels, which cannot, however, be further gone into here.

The advantages thus enumerated are so surprisingly great for almost all vessels that the end in view appears worthy of some effort; the only question is whether we are today so far advanced that installations of this character can be reliably carried out.—"International Marine Engineering."

PRESSURES IN GASOLINE ENGINES.

By G. A. Field.

The following curves, showing variations in per cent. of clearance, compression pressures and temperatures, normal explosion pressures, etc., in internal-combustion engines have been grouped by the writer and found very convenient for rough calculations.

Curve I gives the variations of atmospheric pressure in pounds per square inch with the elevation above sea level in feet. The elevation above sea level is given from zero to 6,000 feet, reading from the top of the scale downward.

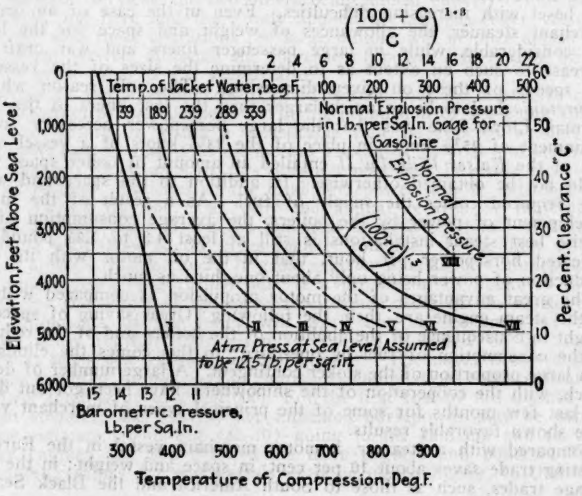

$\left(\frac{100+C}{C}\right)^{1.3}$
2 4 6 8 10 12 14 16 18 20 22
Temp. of Jacket Water, Deg. F.
139 189 239 289 339
100 200 300 400 500
Normal Explosion Pressure in Lb. per Sq. In. Gage for Gasoline
Normal Explosion Pressure
$\left(\frac{100+C}{C}\right)^{1.3}$
I II III IV V VI VII VIII
Atm. Press. at Sea Level, Assumed to be 12.5 lb. per sq. in.
Elevation, Feet Above Sea Level
0 1,000 2,000 3,000 4,000 5,000 6,000
Per Cent. Clearance "C"
60 50 40 30 20 10 0
15 14 13 12 11
Barometric Pressure, Lb. per Sq. In.
300 400 500 600 700 800 900
Temperature of Compression, Deg. F.

Chart for Finding Temperatures and Pressures.

The barometric pressure is given from 11 to 15 pounds per square inch, reading from right to left.

Curves II to VI, inclusive, give the variations in temperature of compression in degrees Fahrenheit with per cent. clearance C for various temperatures of jacket water from 139 degrees F. to 339 degrees F. inclusive. The per cents. of clearance are found at the right, reading from the bottom upward, and the temperatures of compression are found at the bottom, reading from left to right. Curve VII gives the variation of the quantity $\left[\frac{100+C}{C}\right]^{1.3}$ with the per cent. clearance C, and is to be used in the formula given below for determining the compression pressure for various per cents. of clearance and elevations above sea level.

Atmospheric pressure at sea level corrected for volumetric efficiency is assumed to be 12.5 pounds per square inch gage. Compression formula

$$P = P_a\left(\frac{100+C}{C}\right)^{1.3} - P_a.$$

The fundamental formula for the variations of pressure and volume is

$$\frac{P_b}{P_a} = \left(\frac{V_a}{V_b}\right)^n,$$

where

V_a = Volume at beginning of compression;
V_b = Volume at end of compression;
P_a = Pressure at beginning of compression—usually 0.8 or 0.9 atmosphere, depending on the volumetric efficiency;
P_b = Pressure at the end of compression;
C = Clearance (per cent. of piston displacement).

The ratio $\frac{V_a}{V_b}$ = the ratio $\frac{100+C}{C}$.

Therefore,

$$P_b = P_a\left(\frac{V_a}{V_b}\right)^n = P_a\left(\frac{100+C}{C}\right)^n.$$

Reducing to pressure above atmosphere; *i. e.*, subtracting P_a from both sides of the equation

$$P_b - P_a = P_a\left(\frac{100+C}{C}\right)^n - P_a.$$

Let P = pounds per square inch gage = $P_b - P_a$, substituting,

$$P = P_a\left(\frac{100+C}{C}\right)^n - P_a,$$

in which the exponent n is usually assumed to be 1.3. Having determined the atmospheric pressure P_a for the particular elevation and corrected for volumetric efficiency, find the value of the quantity $\left(\frac{100+C}{C}\right)^{1.3}$ for the given per cent. clearance C and solve the equation for P.

Curve VIII gives the normal explosion pressures in pounds per square inch gage for gasoline corresponding to the various values of C.—"Power."

STORAGE OF OIL FUEL.

It is a matter of common knowledge that during the past two years the British Admiralty has made fairly extensive provision for the storage of oil fuel. At Portsmouth, for instance, there are nearly a score of tanks either constructed or under construction, while at Invergordon ten tanks have been laid down. Similar tanks—each capable of holding 6,000 tons—have been erected at other points convenient for oiling war vessels. The Admiralty, it is reported, is accumulating substantial reserves in the storage tanks of the Scottish mineral-oil companies. These tanks are convenient to Rosyth naval base. The oil is of the variety known in the trade as "Lighthouse" oil, being a grade of gas oil. It has been used extensively by the British Admiralty with excellent results. In addition, the Admiralty is a ready buyer of heavier residual oils for use in adapted furnaces. The price for this is a fair one, especially in view of the difficulty which has been experienced in finding a market for such oil.—"The Engineer."

OBSERVATIONS AND NOTES ON THE SEASON CRACKING OF BRASS.

The season-cracking of brass is far more prevalent than the majority of people believe. It is not difficult to find good examples of it, although the majority of people are quite unfamiliar with the appearance or the fact that there is any such phenomenon. It is one of the "diseases" of brass and is not a new ailment, but has been in existence ever since objects have been made of brass sheet.

The season-cracking of brass, so far as known, occurs only on brass or other alloy that has had some work done upon it. The metal must have been rolled, drawn, spun or treated by some other mechanical process. The cast metal which has not been worked at all is apparently free from it. It is sheet-brass articles that give the most trouble, perhaps, because they are more extensive than other forms of this metal, and it is on such articles that season-cracks may be found more than on any other form of brass.

Brass is not the only copper alloy which season-cracks, as the tin bronzes and aluminum bronzes are likewise subject to it, and examples to illustrate it are herewith shown. The yellow brasses, however, are the ones which are subject to it the most, and this alloy seems to be more apt to crack under the right conditions than any other copper alloy. The fact that other copper alloys are subject to season-cracking indicates that the phenomenon is a physical and not a chemical one.

It is believed that the chemical composition of the brass or other alloy is not in any way responsible for its season-cracking, but that the whole question resolves itself into a matter of influences beyond the mixture itself. It may be outside influences, or it may be strains in the metal. In the majority of instances strains are the cause of the cracking, but ammonia and other chemicals evolving it will produce it.

Season-cracks in metals are those which form after the article has been in use for some time or "seasoned." The cracks form spontaneously without any apparent reason, and this very fact renders the phenomenon so mysterious and perplexing. It has often been said that season-cracks are the most exasperating and perplexing of all the ills to which brass is subject, for the reason that they occur without any apparent cause and after the brass has been in use for some time. Were it to occur right away after the goods had been made the matter would not be as bad, but to take place after they have been in use and no outside influence

brought to bear on the brass, renders the subject more perplexing and mysterious to the user.

When season-cracking has been found on a brass article the owner may take it back to the dealer from whom he bought it, who, in turn, sends it to the manufacturer for an explanation. The maker, of course, brings the matter to the attention of the brass-rolling mill which turned out the brass sheet or other form. He frequently threatens to bring suit against the mill for damages caused by the cracking of the brass, and it seems unquestioned that the fault lies in the brass. The rolling-mill proprietor is naturally perplexed and hardly knows what to say or what to do. Here is the case of his brass which cracked open and the evidence is against him. He may adjust the matter with the maker of the goods who used his brass, but he should not have done so, as the difficulty is one for which he is never to blame.

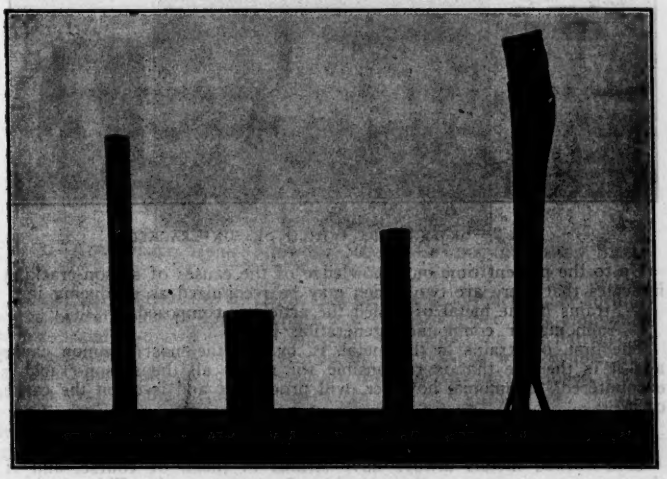


FIG. 1.—ALUMINUM-BRONZE TUBING WHICH SEASON-CRACKED AFTER A LAPSE OF SOME TIME.

As an example of an occurrence such as explained in the preceding paragraph, let the season-cracked acetylene generator shown at the extreme right in Fig. 2 be taken as the case. This was used on the running board of an automobile, and after it had been in use for a year or so (possibly less) it developed cracks. The cracks continued to grow in size to such an extent that it finally became useless and was discarded. When, however, the cracks had developed to such an extent that the generator had seemingly become ruined, the owner took it back to the dealer from whom he purchased it with the complaint that it had cracked. The dealer informed him that he had allowed it to "freeze." He had never heard of season cracks.

It is not a difficult matter to find the majority of such generators that have cracked after they have been in use for some time. Many automobiles are equipped with these brass acetylene generators, and if one examines those which have been on the car and in use for some time, it will usually be found that they have cracked. As will be previously explained, the cause is the generation of ammonia in the reaction between

the calcium carbide and the water used in them. Ammonia, as has been well established, is one of the causes of the season-cracking of brass.

Another example of the way in which brass will season-crack is illustrated in Fig. 3. This is a "Klaxon" horn used on an automobile for two years. The outside shell was of drawn brass. The first year no cracks developed, but after the close of the second year two good-sized cracks appeared and which continued to grow. No influences were brought to bear upon it except the simple action of the atmosphere.

In Fig. 4 is shown a shell of brass made by spinning. Upon standing for several years small cracks developed. This took place several years ago, and since that time the cracks have grown much larger.

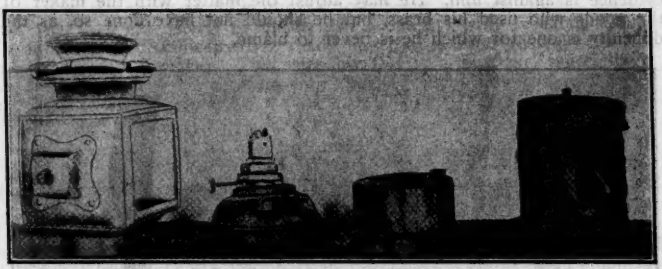


FIG. 2—BRASS GOODS WHICH SEASON-CRACKED.

Up to the present time our knowledge of the causes of season-cracking indicates that there are two which may be recognized as producing it:

1. Strains in the metal of which the article is composed.
2. Ammonia or compounds generating it.

The first, or strains in the metal, is, by far, the most common cause and it is the one that is responsible for nearly all the season-cracking encountered. Ammonia, however, will produce it and is often the cause of it.

STRAINS IN THE METAL.

Cold-worked metals always have strains in them, of course, and if these strains are uneven, then cracking is apt to result. This cracking may result immediately or after a time, depending upon conditions. Fire-cracking is only a modification of season-cracking and is caused by the strains set up in the metal by the heat. It occurs, for example, on German-silver sheet that has not been "broken-down" sufficiently, or, in other words, by using too light a "pinch" in rolling it. The outside is worked and the inside is not to any extent. The metal, therefore, when annealed has uneven strains set up in it and cracks result. In season-cracking, too, the same thing follows although not immediately. There are uneven strains in the metal and it takes time for them to act. It has been found that drawn metal that is evenly worked will not season-crack unless by means of ammonia.

As the majority of season-cracking is caused by strains in the metal, let it be explained how this can happen. It will be found that drawn sheet-brass shells are a very frequent source of this difficulty. The shell is drawn up in a press by means of a punch and die. The relation of the punch to the die may be such that the brass sheet is drawn more on one portion than the other and results in an uneven strain in the drawn shell. This presence of uneven strains is the cause of the season-cracking. Strains may exist in the drawn shell, and if they are uniform, no harm results; but if they are uneven, then season-cracking may follow.

The presence of the uneven strains in drawn-brass shells is the common source of season-cracks and nearly always, if not entirely, results from imperfect die work in the press. There are two methods, one might say, of making a shell in a press. One is by the simple forming by means of the punch and die, and the other is by actually drawing the shell and stretching the metal. It is the forming of the shell and not stretching the metal that is the dangerous kind of press work. It always results in an uneven strain being set up in the drawn shell. If, however, the shell is actually stretched and the metal worked as much as possible in the press, the strains produced are even and season-cracking is not apt to follow.

FIG. 3.—AUTOMOBILE HORN SHOWING SEASON-CRACKS ON BRASS SHELL.

The effect of strains in metal as a cause of season-cracks may be illustrated by referring to Fig. 5. This is a piece of 4 per cent. aluminum-bronze seamless-drawn tubing. The tube was bent over and flattened at the bend, and at the time of the operation no cracks were visible. On standing, however, the crack seen in the illustration developed. The uneven strain in the metal was the cause.

In Fig. 1 are shown a number of pieces of aluminum-bronze seamless-drawn tubing which split open on standing, but only after a lapse of considerable time. These samples of tubing were all aluminum-bronze

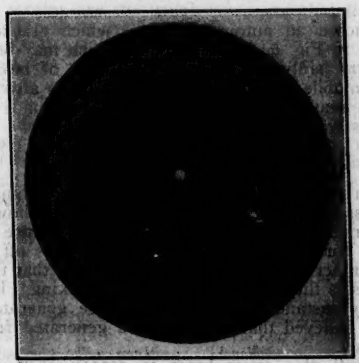


FIG. 4.—SEASON-CRACKS IN SPUN-BRASS SHELL.

and ranged from 4 per cent. to 8 per cent. aluminum content. They were made by the Mannesmann process from a solid billet and then drawn cold. The drawing was not carried out properly, as the draw benches were not powerful enough to produce any working clear through the metal. The result was that the metal was cold-worked on the outside to a considerable extent, but on the inside it received very little. Uneven strains, therefore, existed in the tubes and they season-cracked as illustrated. It is a singular fact that these same tubes, or parts of them, when annealed, fire-cracked in the muffle, and this would seem to indicate that fire-cracking and season-cracking are analogous, although in the case of the fire-cracking they are produced more rapidly.

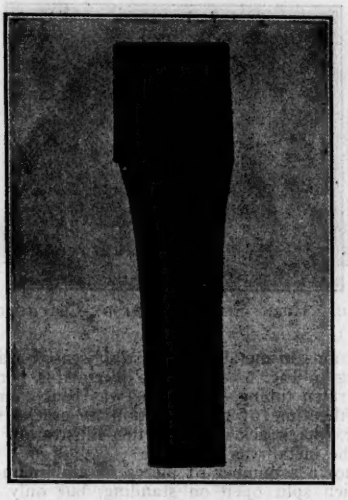


FIG. 5.—4 PER CENT. ALUMINUM-BRONZE TUBING SEASON-CRACKED ON ACCOUNT OF STRAINS.

In Fig. 2 is shown an automobile lamp which cracked badly. Both the top, as shown in Fig. 6, and the fount, which may be seen in Fig. 2, season-cracked very badly. This lamp was made of brass and had been in use on an automobile for some time. In Fig. 2 is also shown a lantern fount, which also season-cracked. This was also made of sheet brass. Both these articles were drawn up in a press.

EFFECT OF AMMONIA.

It has now been well established that ammonia or compounds evolving it will cause brass to season-crack. In Fig. 2 is shown an acetylene generator which cracked very badly when in use. Impure calcium carbide, such as now sold for generating acetylene gas, gives off ammonia when water comes in contact with it and at the same time that the acetylene gas is generated. This is the cause of the season-cracking. It is not difficult to find very many instances of these acetylene generators which have cracked, and it is believed that the ammonia generated from the calcium carbide is the cause.

Ammonia gas will also cause brass to season-crack, and compounds which generate ammonia upon standing likewise produce it. One of

the frequent causes of the cracking is the excretions of animals (which, of course, generate ammonia). When they came in contact with the brass season-cracking will usually result. Many cases of this kind are on record in which animal excretions have been the cause of the season-cracking of brass.

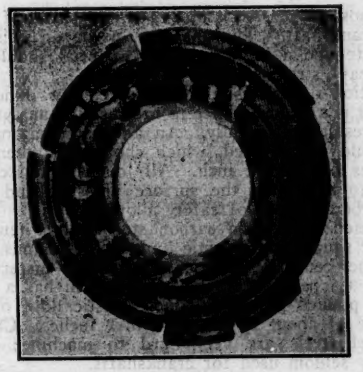


FIG. 6.—TOP OF LAMP SHOWN IN FIG. 2.

Why ammonia should cause it is unknown, and it is one of the mysteries of season-cracking. It may be said that crystallization and season-cracking, in the case of brass, seem to be the same, as the appearance of the fracture is the same in each case. When brass season-cracks the fracture is always coarse and crystalline.

SUMMARY.

The various causes of the season-cracking of brass may be summed up as follows:

1. That the chemical composition of the brass has no direct bearing of the season-cracking.
2. That uneven strains are the usual cause and that they are produced by imperfect press work on the brass article.
3. That all copper alloys are subject to it.
4. That ammonia or any compound evolving ammonia upon decomposition will produce it.
5. That season-cracks are more apt to appear in yellow brass than in any other copper alloy.
6. That the brass rolling mill is rarely at fault, for the season-cracks and the maker of the brass article in the press is the one who should be blamed, except in the case of ammonia when, of course, the user of the brass article is responsible.

In conclusion let it be said that the principal cause of season-cracking is imperfect die work so that internal and uneven strains are set up in the article itself. As one expert manufacturer of brass goods has expressed it, the brass should be "stretched" in the drawing operation and not merely "ironed out" or formed. He states that before this was known, many barrels of drawn-brass shells were made by simple "forming," so to speak, and they all season-cracked within a few days on standing in the barrels after making. The dies were then made over so that the metal was stretched in the press operation and no season-cracking of the shells followed.—"The Brass World."

AN ANALYSIS OF CRANKSHAFT STRESSES.

DETERMINATION OF STRESSES IN TWO- AND THREE-BEARING FOUR-CYLINDER CRANKSHAFTS.

By K. W. Najder.

One of the most expensive and important parts of the automobile motor is the crankshaft. The machine work on this part must be extremely accurate and a high grade of material should be used as it is subjected to heavy strains.

The determination of crankshaft stresses can be done analytically or graphically, and it is a good practice to first use the analytical method and then check the results graphically. An adequate maximum pressure in the cylinder should be assumed, which should be taken as high as 20 to 25 atmospheres per square inch. All journals and crankpins should be dimensioned to withstand the surface pressure and friction in the bearings, and a liberal factor of safety allowed.

The material used is medium carbon steel with a tensile strength of 90,000 pounds per square inch, elastic limit 70,000 pounds, and an elongation of about 15 per cent. in 2 inches. A far better material than medium carbon steel is a 3½ per cent. nickel steel, which has a tensile strength of about 120,000 pounds per square inch, elastic limit of 90,000 pounds and an elongation of about 16 per cent. in 2 inches. Chrome-vanadium and chrome-nickel steels are very hard to machine; therefore these materials are very seldom used for crankshafts.

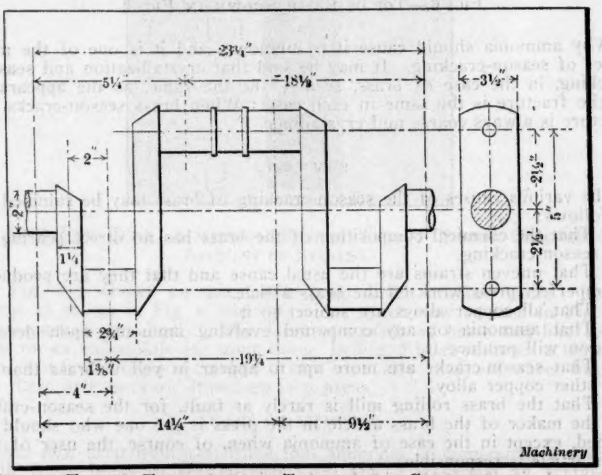


Fig. 1.—Four-cylinder Two-bearing Crankshaft.

The allowable pressure on the journals and crankpins should not exceed 1,000 pounds per square inch. One of the chief requirements of a crankshaft is stiffness, which depends upon the coefficient of elasticity of the material, and the value of this coefficient should be from 30,000,000 to 40,000,000. The arms of the crankshaft should be made of suitable thickness to give the required strength and stiffness, and here the bending stresses are of prime importance. The bending moment varies directly as

the distance from the bearing, and the resistance to bending is directly proportional to the square of the thickness of the arms. However good a designer's judgment may be, and no matter what empirical formulas he has at his disposal, he must seek confirmation of his guesses in figures. This is absolutely necessary when the horsepower of the motor rises above 40, and in racing cars where the horsepower may vary anywhere from 70 to 200, calculations must be relied on in preference to judgment and empirical formulas. In the following, two problems will be completely worked out to illustrate the method of determining crankshaft stresses.

FOUR-CYLINDER TWO-BEARING CRANKSHAFT.

It will be assumed that the motor has a bore of 4 inches and a stroke of 5 inches, and that the maximum explosive pressure is 20 atmospheres per square inch. The maximum pressure on the piston is:

$$P_{max} = \frac{D^2\pi}{4} \times 20 = 250 \text{ atmospheres} = 3750 \text{ pounds.}$$

The connecting-rod pressure $\frac{P_{max}}{\cos\beta}$ is composed of two components, a tangential force T, and a radial force R. (Hütte.)

Let $\alpha = 30$ degrees and $\beta = 7$ degrees.

$$T = \frac{P_{max}}{\cos\beta} \sin(\alpha+\beta) = \frac{3750}{0.9925} \times 0.6018 = 2270 \text{ pounds;}$$

$$R = \frac{P_{max}}{\cos\beta} \cos(\alpha+\beta) = \frac{3750}{0.9925} \times 9.7986 = 3017 \text{ pounds.}$$

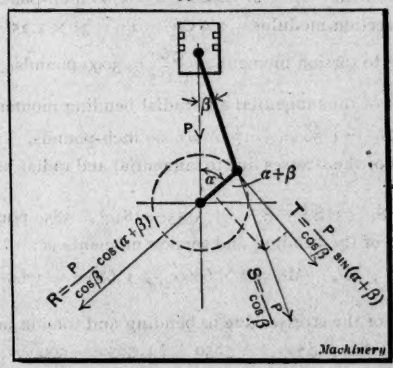


FIG. 2.—DIAGRAM SHOWING METHOD OF RESOLVING CONNECTING-ROD THRUST.

Each of these forces produces pressures on the crankshaft. The greatest pressures will be on the left crankshaft arm when cylinder No. 1 explodes.

Pressure due to tangential force $A_t = \frac{T \times 19\frac{1}{2}}{23\frac{1}{2}} = \frac{2270 \times 19\frac{1}{2}}{23\frac{1}{2}} = 1880$ pounds;

Pressure due to radial force $A_r = \frac{R \times 19\frac{1}{2}}{23\frac{1}{2}} = \frac{3017 \times 19\frac{1}{2}}{23\frac{1}{2}} = 2500$ pounds.

The maximum pressure is:

$$A_{max} = \sqrt{A_t^2 + A_r^2} = \sqrt{1880^2 + 2500^2} = 3125 \text{ pounds.}$$

The maximum pressure on the pin is:

$$\frac{3125}{2 \times 2\frac{1}{4}} = 568 \text{ pounds.}$$

The maximum bending moment on the extreme end of pin is:

$$M_c = 3125 \times 1\tfrac{3}{8} = 4300 \text{ inch-pounds.}$$

The section modulus of the pin is:

$$\frac{D^3\pi}{32} = \frac{2^3 \times 3.14}{32} = 0.7856;$$

$$\text{Stress } S = \frac{4300}{0.7856} = 5470 \text{ pounds.}$$

BENDING MOMENT OF THE LEFT ARM.

M_1 = moment due to radial force = $A_r \times 2 = 2500 \times 2 = 5000$ inch-pounds;

$$\text{Section modulus of arm} = \frac{Ch^2}{6} = \frac{3.5 \times 1.25^2}{6} = 0.90;$$

S_1 = stress due to radial moment = $\frac{5000}{0.90} = 5555$ pounds;

M_2 = moment due to tangential force = $A_t \times 2\frac{1}{2} = 1880 \times 2\frac{1}{2} = 4700$ inch-pounds;

$$\text{Section modulus} = \frac{hC^2}{6} = \frac{1.25 \times 3.5^2}{6} = 2.55;$$

S_2 = stress due to tangential moment = $\frac{4700}{2.55} = 1840$ pounds;

M_t = torsion moment = $A_t \times 2 = 1880 \times 2 = 3760$ inch-pounds;

$$\text{Polar section modulus} = 2/9\ Ch^2 = 2/9 \times 3\tfrac{1}{2} \times 1.25^2 = 1.215;$$

S_t = stress due to torsion moment = $\frac{3760}{1.215} = 3090$ pounds.

The resultant of the tangential and radial bending moments is:

$$M_c = \sqrt{M_1^2 + M_2^2} = \sqrt{5000^2 + 4700^2} = 6860 \text{ inch-pounds.}$$

The resultant of the stresses due to tangential and radial bending moments is:

$$S_c = \sqrt{S_1^2 + S_2^2} = \sqrt{5555^2 + 1840^2} = 5850 \text{ pounds.}$$

The resultant of the bending and torsion moments is:

$$M_r = \tfrac{3}{8} M_c + \tfrac{5}{8} \sqrt{M_c^2 + M_t^2} = \tfrac{3}{8} \times 6860 + \tfrac{5}{8} \sqrt{6860^2 + 3760^2} = 7450 \text{ inch-pounds.}$$

The resultant of the stresses due to bending and torsion moments is:

$$S_r = \tfrac{3}{8} S_c + \tfrac{5}{8} \sqrt{S_c^2 + S_t^2} = \tfrac{3}{8} + 5850 + \tfrac{5}{8} \sqrt{5850^2 + 3090^2} = 6330 \text{ pounds.}$$

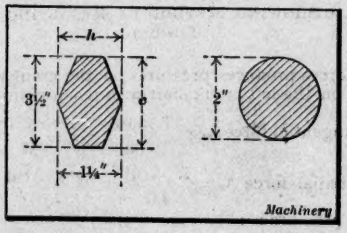


FIG. 3.—CROSS SECTIONS OF ARM AND PIN.

The maximum bending moment on the left journal is:

$M = A_{max} \times 4 = 3125 \times 4 = 12{,}500$ inch-pounds;

$$\text{Section modulus} = \frac{D^3\pi}{32} = \frac{2^3 \times 3.14}{32} = 0.7856;$$

$$S = \text{stress due to maximum bending moment} = \frac{12{,}500}{0.7856} = 15{,}900 \text{ pounds.}$$

STRESSES ON CENTER JOURNALS.

The maximum stresses on both center journals will take place when cylinder No. 2 or No. 3 explodes.

The moment of the left center journal is approximately:

$$M = \frac{3750 \times 5\frac{1}{4} \times 18\frac{1}{2}}{23\frac{1}{4}} = 15{,}600 \text{ inch-pounds;}$$

$$\text{Section modulus} = 0.7856;$$

$$\text{Stress } S = \frac{15{,}600}{0.7856} = 19{,}900 \text{ pounds.}$$

The moment of the right center journal is:

$$M = \frac{3750 \times 14\frac{1}{2} \times 9\frac{1}{4}}{23\frac{1}{4}} = 21{,}300 \text{ inch-pounds;}$$

$$\text{Section modulus} = 0.7856;$$

$$\text{Stress } S = \frac{21{,}300}{0.7856} = 27{,}000 \text{ pounds.}$$

The bending moments and torsions of the center arms are figured in a similar manner to that used in connection with the left arm.

PRESSURE ON THE PIN.

We have found $A_{max} = 3125$ pounds.

The maximum pressure on the pin is $\frac{3125}{2 \times 2\frac{1}{4}} = 568$ pounds.

The circumferential velocity of the pin is:

$$V = \frac{2}{12} \times \frac{\pi \times 1400}{60} = 12.21 \text{ feet per second.}$$

The motor runs at 1,400 revolutions per minute and the coefficient of friction $\mu = 0.05$ (Hütte and Güldner).

The work done by friction is $568 \times 0.05 \times 12.21 = 347$ foot-pounds per second.

It will be remembered that one horsepower equals 550 foot pounds per second; consequently, the lost power due to the friction of the pin is:

$$\frac{347}{550} = 0.63 \text{ horsepower.}$$

The deflection of the crankshaft is obtained from the formula:

$$\text{Deflection} = \frac{P\,l^3}{48\,E\,I}$$

where

P = maximum explosive pressure;
l = length of crankshaft;
E = coefficient of elasticity = about 30,000,000 to 40,000,000;
I = moment of inertia.

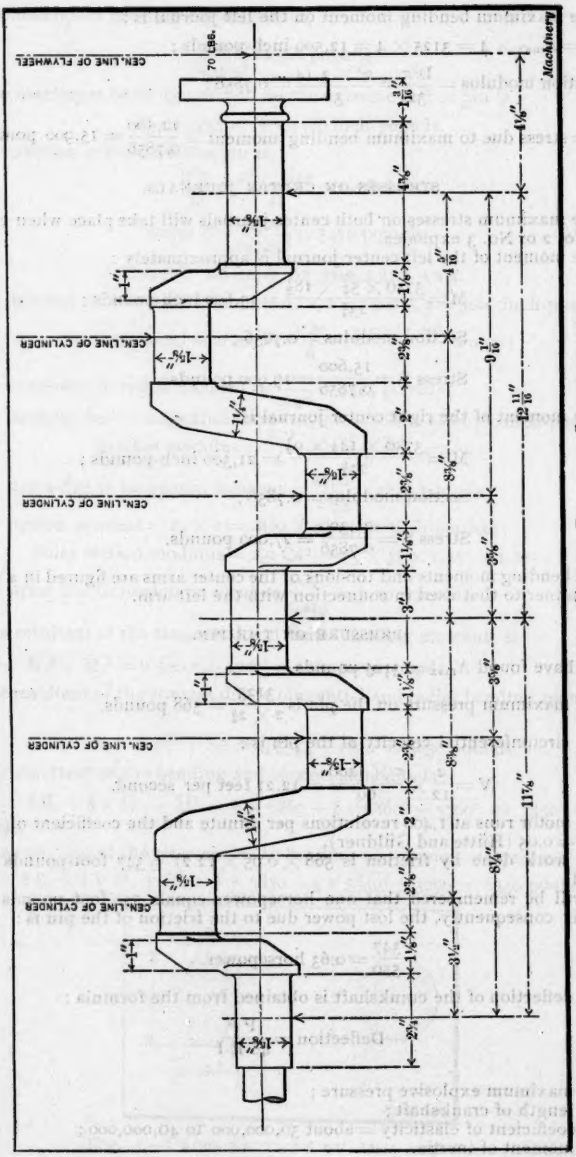


FIG. 4.—FOUR-CYLINDER THREE-BEARING CRANKSHAFT.

FOUR-CYLINDER THREE-BEARING CRANKSHAFT.

We will now consider a four-cylinder three-bearing crankshaft on a motor which has a bore of 4½ inches, a stroke of 4½ inches and a flywheel weighing 70 pounds.

The forces on the crankshaft are :

Connecting-rod pressures = P_0, P_0', P_1' and P_1 ;
Weight of flywheel = P_2 ;
Reactions on bearings = T_0, T_1 and T_2 ;
Bending moments at bearings = M_0, M_1 and M_2.

Clapeyron's formula for a beam supported at three points is :

$$-M_0 l_0 - 2M_1(l_0 + l_1) - M_2 l_1 = \frac{P_0 a_0 (l_0^2 - a_0^2)}{l_0} + \frac{P_0' a'_0 (l_0^2 - a'^2_0)}{l_0}$$

$$+ \frac{P_1 a_1 (l^2_1 - a^2_1)}{l_1} + \frac{P_1' a_1' (l_1^2 - a'^2_1)}{l_1}. \quad \text{(Hütte and Heller.)}$$

To start with, we will put in the above formula:

$$M_0 = 0,\ M_2 = P_2 l_2 = 70 \times 4\tfrac{1}{2} = 288 \text{ inch-pounds.}$$

To be safe, we also assume that there are explosions in two cylinders at a time.

$$P_0 = P_1 = \frac{D^2\pi}{4} \times 25 = 354 \text{ atmospheres} = 5320 \text{ pounds ;}$$

$$P'_0 = P'_1 = \frac{D^2\pi}{4} \times 1.6 = 360 \text{ pounds.}$$

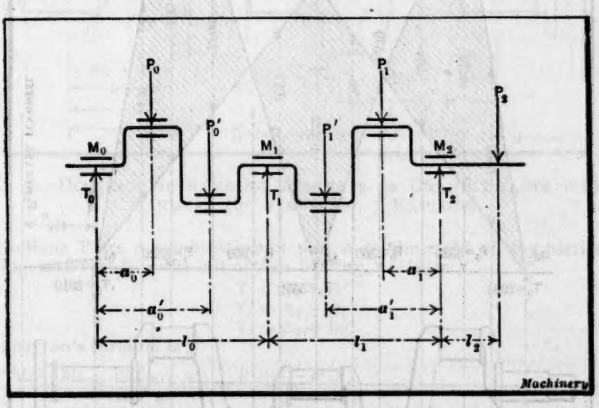


FIG. 5.—DIAGRAM SHOWING MOMENTS, PRESSURES AND REACTIONS IN FIG. 4.

From the crankshaft drawing, Fig. 4, we obtain :

$a_0 = 3\frac{1}{4}$ inches ; $l_0 = 11\frac{7}{8}$ inches ;
$a'_0 = 8\frac{1}{4}$ inches ; $l_2 = 4\frac{1}{2}$ inches ;
$a'_1 = 9\frac{1}{16}$ inches ; $l_1 = 12\frac{11}{16}$ inches ;
$a_1 = 4\frac{5}{16}$ inches ; $P_2 = 70$ pounds = flywheel weight.

Then:

$$-2M_1(11\tfrac{7}{8}+12\tfrac{1}{16})-288\times 12\tfrac{1}{16}=\frac{5320\times 3\tfrac{1}{4}(11\tfrac{7^2}{8}-3\tfrac{1^2}{4})}{11\tfrac{7}{8}}$$

$$+\frac{360\times 8\tfrac{1}{4}(11\tfrac{7^2}{8}-8\tfrac{1^2}{4})}{11\tfrac{7}{8}}+\frac{5320\times 4\tfrac{5}{16}(12\tfrac{1^2}{16}-4\tfrac{5^2}{16})}{12\tfrac{1}{16}}$$

$$+\frac{360\times 9\tfrac{1}{16}(12\tfrac{1^2}{16}-9\tfrac{1^2}{16})}{12\tfrac{1}{16}}-M_1\,49.125-3654=\frac{18{,}580\,(141-12.25)}{11\tfrac{7}{8}}$$

$$+\frac{2970\,(141-68)}{11\tfrac{7}{8}}+\frac{22{,}942\,(161.2-18.5)}{12\tfrac{1}{16}}+\frac{3262{,}5\,(161.2-82)}{12\tfrac{1}{16}}$$

$$-M_1\,49.125-3654=\frac{2{,}614{,}135}{11\tfrac{7}{8}}+\frac{3{,}532{,}213}{12\tfrac{1}{16}}=498{,}538-M_1=\frac{502{,}192}{49.125}$$

$$=10{,}222$$

$$M_1=-10{,}222 \text{ inch-pounds.}$$

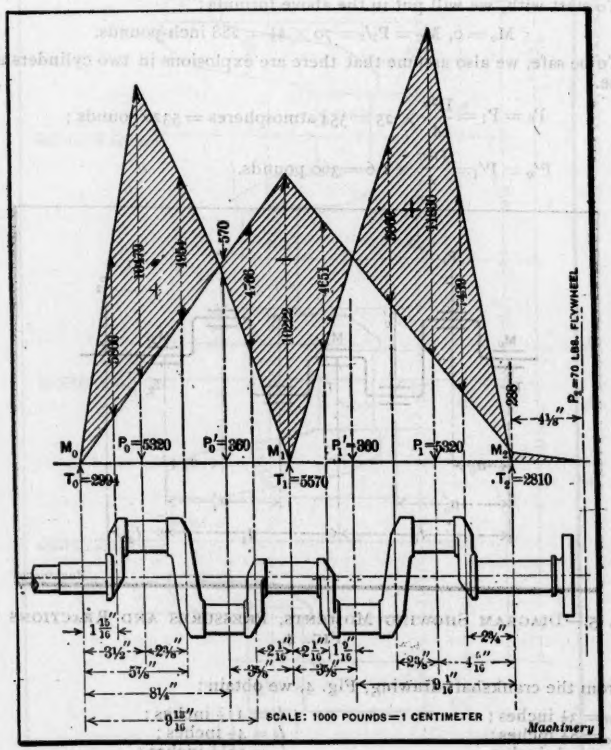


FIG. 6.—DIAGRAM OF BENDING MOMENTS OF CRANKSHAFT WHEN CYLINDERS NO. 1 AND NO. 4 EXPLODE.

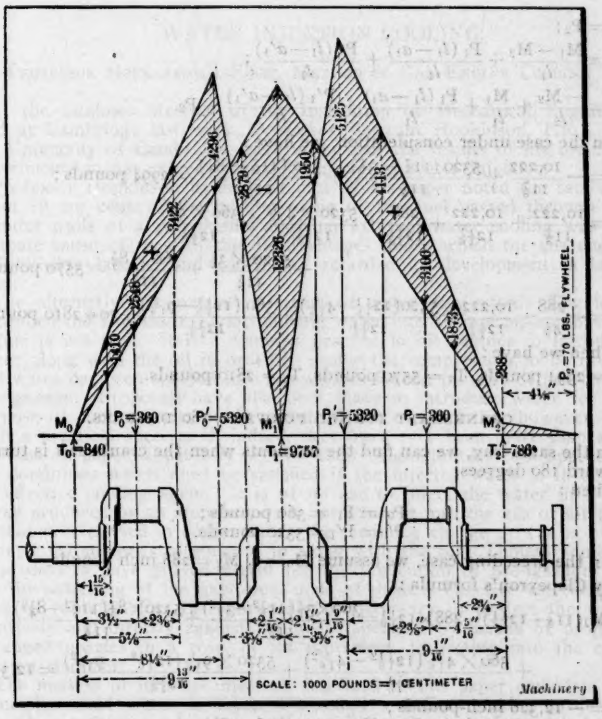


FIG. 7.—DIAGRAM OF BENDING MOMENTS OF CRANK SHAFTS WHEN CYLINDERS NO. 2 AND NO. 3 EXPLODE.

Reactions T are a combination of part A to the right of any particular bearing, and part B to the left of this bearing. (Hütte.)

$$T_0 = A_0 + B_0$$
$$T_1 = A_1 + B_1$$
$$T_2 = A_2 + B_2.$$

Clapeyron's formula is:

$$A_0 = \frac{M_1 - M_0}{l_0} + \frac{P_0(l_0 - a_0)}{l_0} + \frac{P'_0(l_0 - a'_0)}{l_0};$$

$$B_0 = 0;$$

$$T_0 = \frac{M_1 - M_0}{l_0} + \frac{P_0(l_0 - a_0)}{l_0} + \frac{P'_0(l_0 - a'_0)}{l_0};$$

$$A_1 = \frac{M_2 - M_1}{l_1} + \frac{P_1 a_1}{l_1} + \frac{P'_1 a'_1}{l_1};$$

$$B_1 = \frac{M_0 - M_1}{l_0} + \frac{P_0 a_0}{l_0} + \frac{P'_0 a'_0}{l_0};$$

$$T_1 = -\frac{M_1}{l_0} - \frac{M_1}{l_1} + \frac{M_2}{l_1} + \frac{M_0}{l_0} + \frac{P_1 a_1}{l_1} + \frac{P'_1 a'_1}{l_1} + \frac{P_0 a_0}{l_0} + \frac{P'_0 a'_0}{l_0};$$

$$A_2 = P_2;$$

$$B_2 = \frac{M_1 - M_2}{l_1} + \frac{P_1(l_1 - a_1)}{l_1} + \frac{P'_1(l_1 - a'_1)}{l_1};$$

$$T_2 = \frac{-M_2}{l_2} + \frac{M_1}{l_1} + \frac{P_1(l_1 - a_1)}{l_1} + \frac{P'_1(l_1 - a'_1)}{l_1} + P_2.$$

In the case under consideration, we have:

$$T_0 = -\frac{10{,}222}{11\frac{7}{8}} + \frac{5320(11\frac{7}{8} - 3\frac{1}{4})}{11\frac{7}{8}} + \frac{360(11\frac{7}{8} - 8\frac{1}{4})}{11\frac{7}{8}} = 2994 \text{ pounds};$$

$$T_1 = \frac{10{,}222}{11\frac{7}{8}} + \frac{10{,}222}{12\frac{1}{16}} + \frac{288}{12\frac{1}{16}} + \frac{5320 \times 4\frac{5}{16}}{12\frac{1}{16}} + \frac{360 \times 9\frac{1}{16}}{12\frac{1}{16}} + \frac{5320 \times 3\frac{1}{4}}{11\frac{7}{8}} + \frac{360 \times 8\frac{1}{4}}{11\frac{7}{8}} = 5570 \text{ pounds};$$

$$T_2 = -\frac{288}{4\frac{1}{8}} - \frac{10{,}222}{12\frac{1}{16}} + \frac{5320(12\frac{1}{16} - 4\frac{5}{16})}{12\frac{1}{16}} + \frac{360(12\frac{1}{16} - 9\frac{1}{16})}{12\frac{1}{16}} + 70 = 2810 \text{ pounds}.$$

Then we have:

$T_0 = 2994$ pounds, $T_1 = 5570$ pounds, $T_2 = 2810$ pounds.

CRANKSHAFT TURNED FORWARD 180 DEGREES.

In the same way, we can find the moments when the crankshaft is turned forward 180 degrees.

Then:

$$P_0 = P_1 = 360 \text{ pounds};$$
$$P'_0 = P'_1 = 5320 \text{ pounds}.$$

As in the preceding case, we assume $M_0 = 0$, $M_2 = 288$ inch pounds.

By Clapeyron's formula:

$$-2M_1(11\frac{7}{8} + 12\frac{1}{16}) - 288 \times 12\frac{1}{16} = \frac{360 \times 3\frac{1}{4}(11\frac{7}{8}^2 - 3\frac{1}{4}^2)}{11\frac{7}{8}} + \frac{5320 \times 8\frac{1}{4}(11\frac{7}{8}^2 - 8\frac{1}{4}^2)}{11\frac{7}{8}} + \frac{360 \times 4\frac{5}{16}(12\frac{1}{16}^2 - 4\frac{5}{16}^2)}{12\frac{1}{16}} + \frac{5320 \times 9\frac{1}{16}(12\frac{1}{16}^2 - 9\frac{1}{16}^2)}{12\frac{1}{16}} = 12{,}326;$$

$M_1 = -12{,}326$ inch-pounds;

$$T_0 = -\frac{12{,}326}{11\frac{7}{8}} + \frac{360(11\frac{7}{8} - 3\frac{1}{4})}{11\frac{7}{8}} + \frac{5320(11\frac{7}{8} - 8\frac{1}{4})}{11\frac{7}{8}} = 840 \text{ pounds};$$

$$T_1 = \frac{12{,}326}{11\frac{7}{8}} + \frac{12{,}326}{12\frac{1}{16}} + \frac{288}{12\frac{1}{16}} + \frac{360 \times 4\frac{5}{16}}{12\frac{1}{16}} + \frac{5320 \times 9\frac{1}{16}}{12\frac{1}{16}} + \frac{360 \times 3\frac{1}{4}}{11\frac{7}{8}} + \frac{5320 \times 8\frac{1}{4}}{11\frac{7}{8}} = 9757 \text{ pounds};$$

$$T_2 = -\frac{288}{4\frac{1}{8}} - \frac{12{,}326}{12\frac{1}{16}} + \frac{360(12\frac{1}{16} - 4\frac{5}{16})}{12\frac{1}{16}} + \frac{5320(12\frac{1}{16} - 9\frac{1}{16})}{12\frac{1}{16}} + 70 = 786 \text{ pounds}.$$

$T_0 = 840$ pounds, $T_1 = 9757$ pounds, $T_2 = 786$ pounds.

Knowing the reactions T_0, T_1 and T_2, the bending moments at any point of the crankshaft can be easily figured out. We see that the maximum bending moment of the center journal will occur when there are explosions in the second and third cylinder; this moment is 12,326 inch-pounds. The maximum bending moment of the arms takes place when the first and fourth cylinders explode, and is equal to 7,439 inch-pounds, which is the bending moment of the right arm. The combined bending moments and torsions are figured in a similar way to that followed with the four-cylinder two-bearing crankshaft in the first example. From this discussion we see what a small influence the flywheel has upon the crankshaft.—"Machinery."

WATER INJECTION COOLING.

Professor Hopkinson's Novel Method of Gas-Engine Cooling.

At the Summer Meeting of the Institution of Mechanical Engineers held at Cambridge last week, Professor Bertram Hopkinson, F.R.S., of the University of Cambridge, gave in a paper the results of his practical experiments in gas-engine cooling by means of water injection.

Professor Hopkinson in the first part of his paper noted the fact that about 30 per cent. of the heating value of the fuel passed through the cylinder walls of a gas engine, and that external water cooling was the ultimate cause of most of the disadvantages under which the gas engine had hitherto labored and which had retarded its development in large sizes.

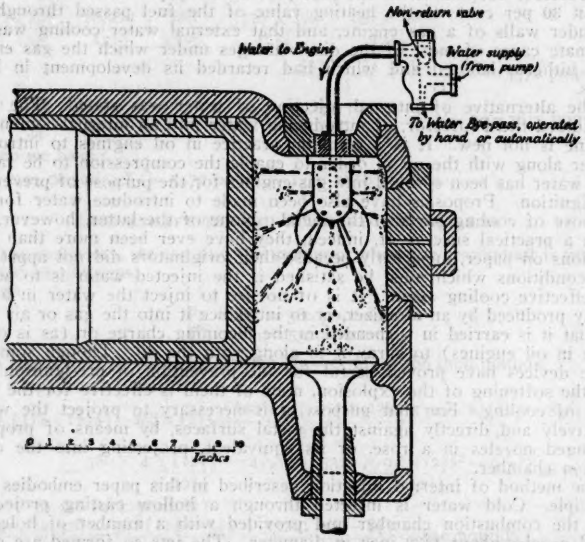
The alternative of internal injection of water was stated. The idea, continued the Professor, of introducing water into an internal-combustion engine is not new. It is a common practice in oil engines to introduce water along with the oil in order to enable the compression to be raised, and water has been sprayed into gas engines for the purpose of preventing pre-ignition. Proposals have also been made to introduce water for the purpose of cooling parts of the metal. None of the latter, however, has been a practical success, if, indeed, they have ever been more than suggestions on paper, apparently because their originators did not appreciate the conditions which must be satisfied if the injected water is to act as an effective cooling agent. It is of no use to inject the water in a fine spray produced by an atomizer, or to introduce it into the gas or air pipe, so that it is carried in suspended in the incoming charge or (as is often done in oil engines) to spray it in along with the oil. Though some of these devices have proved useful for the prevention of pre-ignition and for the softening of the explosion, none of them is effective for the purpose of cooling. For that purpose it is necessary to project the water positively and directly against the metal surfaces, by means of properly arranged nozzles in a rose, or its equivalent, projecting into the combustion chamber.

The method of internal injection described in this paper embodies this principle. Cold water is injected through a hollow casting projecting into the combustion chamber and provided with a number of holes or small nozzles about 1/32 inch in diameter. The jets so formed are comparatively coarse, so that even when projected into the flame the water reaches the part of the wall against which it is directed with but little evaporation on the way. The jets are directed to all parts of the surface of the combustion chamber and against the face of the piston.

When the author first began to consider the use of internal injection as a means of cooling, these difficulties of corrosion and lubrication seemed to be an insuperable bar, until it occurred to him that they could probably be overcome by the simple device of regulating the amount of water injected in such a way that the temperature of the whole of the engine is kept well above 100 degrees C. Under such conditions (which, of course, are only rendered possible by the absence of all external water cooling) every drop of injected water is boiled when it reaches the walls, and no liquid can accumulate.

The practical application of this system of cooling has been much facilitated by a discovery made by the author soon after he began experimenting with it. It was well known from the experiments of Dr. Dugald Clerk, the author, and others, that the rate of heat flow from the gas into the metal is far more rapid at, and soon after, the moment of ignition than at any other time. It seemed likely from these experiments that for practical purposes the heat flow into the barrel of the cylinder during the last three-fourths of the expansion stroke might be so small compared with that in the first period that direct cooling of this portion of the cylin-

der could be dispensed with altogether. This anticipation has been found to be correct. It is sufficient to inject water on to the surface of the combustion chamber and the head of the piston only, the whole of the cooling of the barrel being effected by conduction into the piston, which is itself kept cool by the projection of water on to the head when it is near the in-center. This, of course, is the opposite of what occurs in a jacketed engine, in which the heat flows from the piston into the jacketed barrel. By taking advantage of this fact, the application of water is confined to places where it can do no harm, none falling on the sliding



surfaces. This is a point of some importance if the water contains much dissolved matter. The experimental engine described below has been worked for some thousands of hours, and is now working with a very hard water containing about 0.35 gramme of salts to the liter (25½ grains to the gallon), so that the surface of the combustion chamber and the face of the piston have become thickly encrusted with salts. Yet no trouble whatever has arisen, because no water has been allowed to fall on the sliding surfaces. The absence of pre-ignition under such conditions is also noteworthy and shows the efficiency of this method of cooling.

TRIALS OF 50-B.H.P. ENGINE.

In order to put these ideas to a practical test, a Crossley engine, 11½ inches diameter by 21 inches stroke, rated at 40 B.H.P. (with coal gas) at 180 revolutions per minute, was fitted with a new cylinder consisting of a plain barrel without any water jacket. The valve motions were retained, and the valves and the shape of the combustion chamber were the same, the only change being the removal of all external water cooling. It was, therefore, possible to make an accurate comparison between the performance of the engine with the new system of cooling, and the results of the measurements of fuel economy and the temperatures of the piston and other parts of the engine which had been made by the author on the

same engine when jacketed. The compression ratio in the engine is 6.37, giving a compression pressure of about 175 pounds per square inch absolute. This is higher than is usual and proved, when the engine was jacketed, to be too high for ordinary practical working. The successful working of the new cylinder, therefore, constitutes a satisfactory proof of the freedom from pre-ignition which is characteristic of cooling by water injection.

A section of the new cylinder with water injection rose is shown in Fig. 1. The injection rose is a hollow casting, projecting into the combustion chamber. There are about twenty-five holes in the rose, each 1/40 inch in diameter, and the jets proceeding from these are directed, as shown, against all parts of the combustion chamber and piston head. There is no jet on to the exhaust valve, as it has been found that the drip from the rose is sufficient to keep this cool. The water is injected by a simple plunger pump of the same kind as that used for the injection of fuel in Messrs. Hornsby's oil engines. It is driven by a cam on the valve shaft, whereby a charge of water is injected once in a cycle. The pump stroke commences about 30 degrees before and finishes about 30 degrees after the point of ignition, so that water only goes in at a time when practically the whole of the sliding surface of the barrel is covered by the piston.

FUEL ECONOMY AND CONSUMPTION OF WATER.

Immediately after erection with the new cylinder the engine was run continuously for 120 hours on an electrical load with coal gas. Continuous observation was kept of the gas consumption and of the load. The engine developed during this period 43 B.H.P. on the average, and ran very smoothly and steadily. The average mean effective pressure was 101 pounds per square inch. When jacketed, the engine would not develop more than 40 B.H.P. continuously without overheating, and mixtures giving a mean pressure of more than 100 pounds per square inch produced excessive maximum pressures (over 500 pounds) with violent thumping explosions. The reduction in maximum pressure, under these circumstances, by water injection is over 100 pounds per square inch, and the effect is very marked, the explosion becoming almost inaudible. This effect of the presence of steam in the explosive charge is, of course, well known, but the quantity of steam formed in an engine cooled in this manner is so large that it constitutes a substantial advantage of the method. It will be noticed that the formation of the steam does not involve any thermodynamic loss, such as occurs when water is sprayed into the cylinder in an atomized condition and evaporated before reaching the walls, since the heat used is that which would otherwise be wasted in the jacket water.

The quantity of water used on this trial was on the average 102 pounds per hour, equivalent to 2.4 pounds per B.H.P.-hour. The temperature of the engine varied from 150 degrees to 180 degrees C. No water was visible on the piston or the spindles of the valves, and when the engine was stopped at the end of the trial the inside of the combustion chamber was found to be perfectly dry. When the engine was jacketed and giving the same power for short periods the jacket water removed about 67,000 B.t.u. per hour, which would be sufficient to evaporate 108 pounds of water at a temperature of 20 degrees C. under atmospheric pressure. The agreement between the available heat and the amount of water evaporated is satisfactory, such difference as there is being accounted for partly by greater radiation loss consequent on the higher temperature of the engine, and partly by the reduction in flame temperature produced by the steam, which somewhat reduces the total amount of heat passing into the walls.

The engine consumed in this trial 15 cubic feet of Cambridge coal gas per B.H.P.-hour reckoned at atmospheric temperature and pressure. This is approximately the same as it burnt when developing the same power

for short periods when jacketed. Tests at other loads have shown that with a weak mixture the gas consumption is slightly increased by the water injection, but with very strong mixtures it is a trifle less. The difference, however, does not exceed 5 per cent. either way, and on the average it may be said that the economy is unaffected by the use of this method of cooling.

RELIABILITY AND WEAR UNDER ORDINARY WORKING CONDITIONS.

After the trial just described the engine was put to drive a dynamo in a factory engine room. Its speed was increased from 180 to 195 revolutions per minute. It was left in the hands of the ordinary engine-room staff for several weeks, and was worked continuously for long periods of time at excessive loads. During this time it developed at times 50 B.H.P. with coal gas for several hours together—an increase of 25 per cent. on the maximum continuous load which it could safely carry when jacketed. It is left to itself like an ordinary gas engine, giving no trouble at all, and has now been in regular work for two years, the total time of running being 5,000 hours.

Anthracite coal is used in the producer, and this coal contains a considerable proportion of sulphur. Yet there has been no trace of corrosion in the engine. That the cororsion would be rapid if liquid water were allowed to accumulate is shown by the experience with the nozzles in the injection rose.

The cylinder was at first lubricated with a thick oil, such as is used with superheated steam in steam engines. A gallon of this oil, costing 3s. 3d. lasts for 160 hours, equivalent to about one farthing per hour, or, say, 0.006d. per B.H.P. hour. The lubrication was entirely satisfactory. During the past year "Super Mazoot" oil, supplied by the Henry Wells Oil Co., has been used. This oil is much cheaper, but it is not quite so clean. The balance of advantage remains with it, however, and its use is being continued. Accurate measurements of the cylinder and piston have been made, with the following results:

	As delivered from makers.	After 200 hours' running.	After 1,000 hours' running.	After 4,000 hours' running.
	inches.	*inches.*	*inches.*	*inches.*
Piston, breach end.....	11.475	11.474	11.4735	11.472
crank end.....	11.490	11.489	11.489	11.489
Cylinder, breach end.....	11.50	11.50	11.50	11.505
crank end.....	11.502	11.502	11.502	11.502

It is quite certain that the combined wear (on cylinder and piston together) in the course of 4,000 hours has nowhere exceeded one-hundredth of an inch. Over the greatest part of the surfaces it is much less, and in many places the tool marks are still visible.

The ordinary working temperature of the cylinder is about 160 degrees C., but the engine will run satisfactorily at any temperature between 120 degrees C. and 200 degrees C. In order to keep the temperature between these limits, some regulation of the water supply in accordance with the load is necessary.

SAFETY PLUG.

It is one of the advantages of this method of cooling that failure of the water supply—such as may occasionally occur owing to the pump valve sticking—entails nothing worse than a temporary shut down. If the

water cooling of the piston in a large gas engine is stopped for a few minutes the engine is very likely to be wrecked by the seizing of the expanding piston in the cold cylinder. But if the engine is cooled by injection, nothing of the kind can occur, because the various parts of the engine all heat up together. If the water supply be shut off the engine heats up quite slowly, and if unattended it stops by the occurrence of pre-ignitions arising usually from the injection rose. Even in a 36-inch cylinder it has been found that no serious harm is done by such an event.

In order to minimize the inconvenience and to guard against any danger arising from failure of the water supply, however, the engine is provided with a fusible plug, screwed into the wall of the combustion chamber. Should the temperature rise above about 200 degrees C.—quite a safe working temperature—the plug melts and the noise of the escaping gases warns the attendant. This simple device has been thoroughly tested and has been found absolutely reliable. If, with the engine running at full load, the water be shut off completely, the engine heats up quite slowly, taking perhaps ten minutes or a quarter of an hour to reach the point at which the plug goes. There is thus ample time, before the engine becomes dangerously overheated, to reduce the load (if necessary) and to attend to any small defect such as a stock valve or blocked pipe. A screw-down valve is provided for closing the hole made by the fusion of the plug, so that it is not necessary to stop the engine for its replacement until a convenient time.

TRIALS OF LARGE ENGINES.

From the nature of this method of cooling it seemed almost certain that its effectiveness would be independent of the size of the engine. Each square foot of metal receives a certain amount of heat from the gas, and it is only necessary to deliver to that square foot as much water as will be evaporated by the heat which it receives. The heat received per unit area is greater in a large engine than in a small one, but it did not seem probable that this would materially affect the matter. The truth of this anticipation has been proved by applying the method to the cooling of larger engines—one an engine of 18½ inches bore giving 105 B.H.P., the other a 1,000-H.P. Oechelhauser of 36 inches bore.—"Gas and Oil Power," Aug. 7, 1913.

SHIPS.

UNITED STATES.

The following was the total degree of completion of vessels under construction for the U. S. Navy on August 1, 1913:

No.			
	BATTLESHIPS:		
34	*New York*	Navy Yard, N. Y	85.8
35	*Texas*	Newport News Co	91.7
36	*Nevada*	Fore River Shipbuilding Co	40.3
37	*Oklahoma*	New York Ship Building Co	37.7
38	*Pennsylvania*	Newport News Co	2.0
	DESTROYERS:		
43	*Cassin*	Bath Iron Works	99.3
44	*Cummings*	Bath Iron Works	90.4
45	*Downes*	New York Ship Building Co	63.7
46	*Duncan*	Fore River Shipbuilding Co	98.0
47	*Aylwin*	Wm. Cramp & Sons	96.9
48	*Parker*	Wm. Cramp & Sons	93.5
49	*Benham*	Wm. Cramp & Sons	92.3
50	*Balch*	Wm. Cramp & Sons	91.8
51	*O'Brien*	Wm. Cramp & Sons	7.1
52	*Nicholson*	Wm. Cramp & Sons	7.3
53	*Winslow*	Wm. Cramp & Sons	7.0
54	*McDougal*	Bath Iron Works	12.6
55	*Cushing*	Fore River Shipbuilding Co	12.6
56	*Ericsson*	New York Ship Building Co	9.6
	FUEL SHIPS:		
10	*Nereus*	Newport News Co	93.6
13	*Kanawha*	Navy Yard, Mare Island	1.3
14	*Maumee*	Navy Yard, Mare Island	1.3
	SUBMARINES:		
27	*G*-2	Lake T. B. Co	88.1
31	*G*-3	Lake T. B. Co	69.6
26	*G*-4	Wm. Cramp & Sons	93.4
28	*H*-1	Union Iron Works	94.5
29	*H*-2	Union Iron Works	93.0
30	*H*-3	Seattle Construction and Dry Dock Co	91.4
32	*K*-1	Fore River Shipbuilding Co	85.9
33	*K*-2	Fore River Shipbuilding Co	85.0
34	*K*-3	Union Iron Works	81.6
35	*K*-4	Seattle Construction and Dry Dock Co	78.6
36	*K*-5	Fore River Shipbuilding Co	72.9
37	*K*-6	Fore River Shipbuilding Co	72.7
38	*K*-7	Union Iron Works	71.9
39	*K*-8	Union Iron Works	71.0
40	*L*-1	Fore River Shipbuilding Co	6.1
41	*L*-2	Fore River Shipbuilding Co	6.1
42	*L*-3	Fore River Shipbuilding Co	6.1
43	*L*-4	Fore River Shipbuilding Co	6.1
44	*L*-5	Lake T. B. Co	0.0
45	*L*-6	Lake T. B. Co	0.0
46	*L*-7	Lake T. B. Co	0.0
47	*M*-1	Fore River Shipbuilding Co	5.5

	SUBMARINE TENDER:		
1	*Fulton*	Fore River Shipbuilding Co	14.3
	GUNBOATS:		
20	*Monocacy*	Navy Yard, Mare Island	54.0
16	*Palos*	Navy Yard, Mare Island	54.0
19	*Sacramento*	Wm. Cramp & Sons	35.3
	DESTROYER TENDER:		
2	*Melville*	New York Ship Building Co	0.0

CHILI.

STEAM TRIALS OF THE CHILIAN TORPEDO-BOAT DESTROYER *ALMIRANTE LYNCH.*

Considerable interest attached to the steam-power trials of the torpedo-boat destroyer *Almirante Lynch*, the first of six similar vessels ordered from Messrs. J. Samuel White & Co., Limited, of East Cowes, Isle of Wight, by the Chilian Government, for whom Sir Philip Watts, K. C. B., is acting as technical adviser. This craft is the largest of the class so far built, with the exception of the special torpedo-boat destroyer *Scout*, built for the British Navy. These destroyers, which we intend to illustrate fully later, have a length of 330 feet over all and 320 feet on the water line, the molded breadth being 32 feet 6 inches and the molded depth 21 feet. The designed draught approved for the trial was 9 feet 9 inches, at which the vessel displaced 1,530 tons. The vessels will have remarkable seagoing qualities, owing to the height and length of the forecastle, which is about 100 feet long. The armament is particularly powerful. On the forecastle deck there are two 4-inch 40-caliber quick-firing guns abreast, with a very considerable arc of training abaft the beam. On a raised platform, which is aft of the forecastle, are two more 4-inch guns, arranged to fire over the forecastle deck, also with considerable arc of training abaft the beam. Two other 4-inch guns are placed abreast on the upper deck aft, so that they also have a very wide range. A raised platform, extending across the ship, is built in the way of these guns, with a hinged portion outboard, to enable the guns to be worked at the extreme angles of training aft. Four Maxim guns are placed under the boats on the upper deck. Two torpedo tubes are placed between the funnels and one aft of the engine-room skylight, all on the center line.

A notable feature in the ship is the extensive radius of action provided for, while she is also fitted with both the Marconi and Telefunken systems of telegraphy. In her general equipment she is in advance of many vessels of the class. This applies to rangefinders, navigating appliances, and boats, the latter including a motor boat with a Mumford paraffin motor, two whalers, two gigs and one dinghy. Great care, too, has been devoted to the protection and insulation of the magazines, while the accommodation for the officers has had special consideration, not only in respect of its spaciousness, but its ventilation. There are two electric generators of a collective power of nearly 50 kw., and two refrigerating machines.

The propelling machinery is of the Parsons impulse and reaction turbine type, and is mounted on three propeller shafts, the designed power being 30,000. The center shaft is driven by the main high-pressure turbine, with which is incorporated a cruising element. On the wing shafts there are the low-pressure turbines, with each of which there is incorporated an astern turbine, arrangements being made to cut off the steam supply from the center shaft and pass it direct to the astern tur-

bines for going astern. Maneuvering can also be done with only the low-pressure turbines on the wing shafts.

The full-power trial took place on the measured mile at Skelmorlie, on the Clyde. The designed power of 30,000 horsepower was exceeded, and the guaranteed speed was thus easily maintained, not only over the six runs over the measured mile, but on the six-hours continuous trial. The mean speed on the measured mile was 31.7 knots, and on the six-hours run 31.85 knots; coal only was used on the full-power trial, and at the large horsepower developed the boilers, which are of the White-Forster type, gave splendid results as regards coal consumption, absence of smoke, and flaming at funnels, &c. We tabulate the results:

OFFICIAL SIX-HOURS FULL-SPEED TRIAL AT SKELMORLIE, JULY 11, 1913. TRIAL RESULTS ON THE MILE.

Number of Run.	Time.	Speed.	Mean Revolutions.	S.H.P. Mean.
	m. s.	*knots.*		
1	1 53	31.86	615.1	30,300
2	1 51	32.43	611.7	30,740
3	1 57	30.77	605 7	29,525
4	1 51	32.43	603.3	29,685
5	1 56	31.03	621.7	31,035
6	1 60	32.73	623.4	31,135
Admiralty mean of means		31.683	609.2	...

Mean over Six-Hours Trial.

Speed, knots	31.85
Revolutions	612.5
Shaft horsepower	29.792
Mean coal per shaft horsepower per hour, pounds	1.85

At the time of trial the displacement of the vessel corresponded to that of her complete seagoing condition, with all armament, officers and crew, and stores, spare gear, and 200 tons of coal on board.—"Engineering."

ENGLAND.

BRITISH BATTLE CRUISER *TIGER*.

The new British cruiser *Tiger* was laid down at the Clydebank shipyard early in 1912. The British Admiralty have, as usual, issued no particulars of the ship, but the broad features of the design which are given here may be taken as fairly accurate. The *Tiger* will be the largest, the fastest, the best protected and the most powerfully armed ship of the type in the world. With her great speed she could keep at such a distance as to render any attack upon her ineffective, while able still to do great destruction to the opponent. It is interesting to show in tabular form the progressive steps of the past seven years in battle cruisers for the British Navy.

	Invincible.	*Lion.*	*Tiger.*
Date of Launch.	1907.	1910.	1913.
Length overall.....	562 ft. 0 ins.	700 ft. 0 ins.	730 ft. 0 ins.
Length B. P.....	530 ft. 0 ins.	660 ft. 0 ins.	680 ft. 0 ins.
Breadth.....	78 ft. 0 ins.	86 ft. 6 ins.	90 ft. 6 ins.
Draught.....	26 ft. 0 ins.	27 ft. 6 ins.	28 ft. 6 ins.
Displacement.....	17,250 tons.	26,350 tons.	28,000 tons.
I.H.P.....	41,000	70,000	99,000
Speed.....	25 knots.	28 knots.	30 knots.
Armor belt.....	7 ins.	9 ins.	11 ins.
Main battery.....	8 12-in. guns.	8 13.5-in. guns.	8 14-in. guns.
Secondary battery.....	16 4-in. guns.	20 4.7-in. guns.	24 6-in guns.
Torpedo tubes.....	5 18-in.	5 21-in.	5 21-in.

The propelling machinery is of the Parsons steam turbine type, arranged for four screws. The turbines are designed to give 99,000 horsepower, and are placed in two watertight compartments, so that in each engine room there is one high-pressure ahead, and one high-pressure astern turbine mounted separately on the outer shaft, and a low-pressure ahead and astern turbine within one casing on the inner shaft. Four steel plate condensers are placed aft, together with the centrifugal pumps and other auxiliaries. The whole of the machinery arrangements are such as to preserve the independence of the port and starboard sets of machinery and to allow either set to be worked when all parts of the other are disabled. There are two air pumps and two circulating pumps for each pair of main condensers.

There are forty-two water-tube boilers of the Yarrow type, working at a pressure of 235 pounds per square inch, and arranged for forced draft with closed stokeholds, and they are placed in seven boiler rooms. The coal-bunker capacity is about 4,000 tons, and provision is also made for carrying 1,000 tons of fuel oil.

The ship has four propeller shafts, with one three-bladed, solid cast-bronze propeller on each. She has two rudders of the underwater balanced type, with two sets of screw-steering gear worked by one steam-steering engine. The steering gear and rudder heads are placed under the protective deck. The ship's stern has a graceful curve and is made of cast steel, and it has no ram.

It was in the *Invincible* class that the all-big-gun principle was first adopted. They mounted eight 12-inch guns in four turrets, one forward and one aft, while the two on the broadside amidships were placed diagonally in order that they might be used on either broadside. In the *Tiger* this arrangement of guns has been discontinued, and her turrets are all arranged on the center line of the ship. The two turrets forward of the bridge are placed at different levels, so that the four guns may fire ahead and on each broadside. The midship pair will also fire on either broadside. The astern turret is on the upper-deck level, and the superstructure has a long embrasure to give this pair of guns a wide arc of training before the beam.

The guns of the main battery are the new 14-inch pattern. The guns of the secondary battery are 6-inch quick-firing, and these are placed in the superstructure. The torpedo tubes are all under water. Torpedo-defense nets are fitted all fore and aft, and they are suspended from sixteen booms on each side of the ship.

There are two lifeboats hung in davits, and motor launches and other small boats are stowed above the superstructure.

The *Tiger* is a powerful looking ship, with three vertical smokestacks and one mast. She is provided with the usual wireless-telegraphy arrangements. The side armor is in three strakes, and extends to within about 60 feet of the stem and about 70 feet of the stern. For a length amidships two of the strakes are 11 inches thick, and the top strake is 7 inches, all tapering to 4 inches thick at the forward and after ends. The turrets are also of 11-inch armor.

The designed speed of the vessel is 30 knots, which will doubtless be greatly exceeded on the full-power trial.—"International Marine Engineering."

H.M. TORPEDO-BOAT DESTROYERS *SHARK, SPARROWHAWK* AND *SPITFIRE.*

We illustrate one of the twenty vessels for the British Navy, designed by Sir Philip Watts, K. C. B., when Director of Naval Construction at the Admiralty, and built in various establishments under the 1911–12 program. The vessel illustrated is one of three, the hulls of which were constructed by Messrs. Swan, Hunter & Wigham Richardson, Limited, while the propelling machinery was designed and constructed by the Wallsend Slipway and Engineering Company, Limited, Wallsend-on-Tyne, and all three—the *Shark, Sparrowhawk* and *Spitfire*—have completed their trials most successfully and have passed into commission.

These vessels, like their sister ships, have a length of 260 feet, a beam of 27 feet, a draught of 9 feet 4 inches, and a displacement tonnage of 935 tons, of which 373 tons are due to the weight of the hull. The vessels have been designed to steam at full speed in a heavy sea, and thus they have an exceptionally high forecastle with a conning tower and bridge behind the after end of this forecastle, the height of the bridge being about the level of the top of the funnel, although the fore funnel is much higher than the others. The armament includes three 4-inch guns, one mounted on the forecastle, one right aft, and another near the stern. There are two torpedo-launching tubes, one amidships and one aft.

The propelling machinery, as shown in Fig. 1, which illustrates the arrangement for driving the twin screws, with the condensers alongside each unit, was designed to develop 24,500 shaft horsepower in order to ensure a speed of 29 knots. This result was easily achieved, the average speed of the three vessels on their six runs over the measured mile, made in rough weather in each case, being about 30¾ knots, with an average mean shaft horsepower of about 25,400 for 635 revolutions. This power was maintained for eight hours in all three vessels, the oil consumption working out at about 1 pound per shaft horsepower per hour.

These twenty destroyers are the first with twin screws; the earlier vessels had the three-screw arrangement of turbines. Twin screws have much in their favor, whether considered from the standpoint of facility of operation, maneuvering, supervision, or with regard to the question of propulsive efficiency. There are, as illustrated, two independent turbines, each driving its own shaft and propeller. Each turbine is of the ordinary Parsons type, with ahead-going and astern-going sections incorporated in the same casing. An impulse wheel with special blading or buckets is fitted to both the ahead and astern turbines, to deal with the highest pressure steam, the ahead impulse wheel being at the forward end, and the astern impulse wheel at the aft end. Steam is admitted to the ahead and astern turbines through groups of nozzles, each group having a controlling valve. The steam after leaving the impulse wheels is further expanded through a number of stages fitted with the usual reaction blading of the Parsons type, the combination of the impulse and reaction sections resulting in a most economical arrangement. The number of groups of nozzles open to steam at any one time can be regulated to suit the condition under which the turbine is working, and by this means an excellent economy at low or cruising powers, as well as at high powers, is successfully ensured. The position of the controlling valves for steam to the nozzles for the ahead-going turbines is clearly indicated in our illustration, while a further reference to this shows immediately above these valves the specially designed main steam strainers and balanced expansion joints.

In the wings of the vessel are placed the condensers connected re-

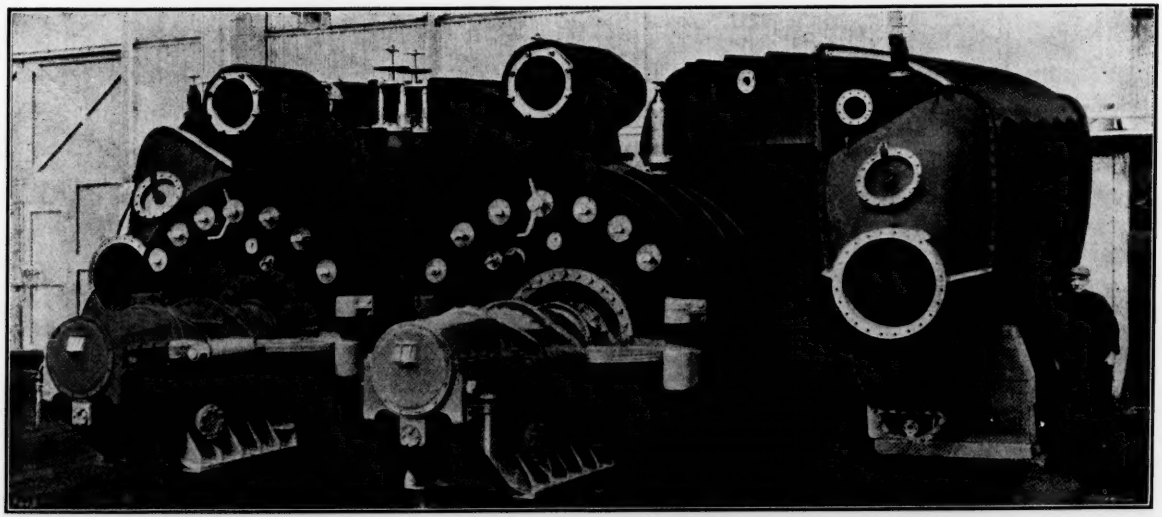


FIG. 1.—TWIN-SCREW PARSONS IMPULSE AND REACTION TURBINES FOR H. M. TORPEDO-BOAT DESTROYER "SHARK."

spectively to the port and starboard turbines. Our illustration shows these condensers relative to the turbines themselves, together with the main exhaust bends, in position. From this illustration it will be obvious that much careful designing was involved in order that the whole plant should be accommodated in the space at disposal. These condensers are of the Weir "Uniflux" type, embodying all the latest improvements, and this type of condenser continues to prove its effectiveness in the most marked manner, in addition to the attainment of considerable saving in space.

Air pumps of the well-known "Dual" type, supplied by Messrs. G. & J. Weir, Limited, of Cathcart, Glasgow, are provided to work in conjunction with the condensers, the efficiency of these pumps being thoroughly demonstrated during the trials. For the attainment of the high vacuum necessary with turbine machinery it is essential that there shall be an ample and uniform provision of circulating water for the condensers, and during the trials the centrifugal circulating pumps, which were supplied by Messrs. W. H. Allen, Son & Co., Bedford, proved themselves more than equal to the requirements. These pumps are of this firm's special design, having turbine discs; each pump is driven by a double-acting enclosed engine fitted with forced lubrication.

In addition to the above there are the usual other auxiliaries which obtain in this class of vessel, the satisfactory working of which contributed in no small degree to the success of the trials. The main and auxiliary feed pumps, feed-water heater, oil-lubricating pumps and oil-fuel pumps were all supplied by Messrs G. & J. Weir, Limited, Glasgow, while this firm also provided the distilling machinery, consisting of a vertical evaporator of the Admiralty "Express" type, a horizontal-type distilling condenser, together with a combination circulating fresh-water and brine pump. The fire and bilge pump has been supplied by Messrs. A. G. Mumford, Limited, Colchester, and is of their well-known "Simplex" type. The forced-draft fans are of the single-inlet "multivane" type, driven by double-acting enclosed engines fitted with forced lubrication, these fans and engines having been supplied by Messrs. M. Paul & Co., Limited, Dumbarton. The electric generating machinery and the air-compressing machinery were supplied by Messrs. Peter Brotherhood, Limited, Peterborough, while the steering engines and gear were supplied by Messrs. Napier Brothers, Limited, Glasgow.

The boilers are of the Yarrow water-tube "Express" type, and were entirely constructed at the engine builders' works at Wallsend. They are of the design and arrangement now usually adopted for this class of vessel, and embody all the more recent improvements in minor details which experience has shown to be beneficial. The automatic feed-water regulators, as fitted to the boilers, were supplied by Messrs. A. G. Mumford, Limited, Colchester. The fuel used for the boilers during the trials was a heavy oil of the quality as generally supplied to the Admiralty. The oil-burning system is of the usual Admiralty pressure system, the working of which on the trials was eminently satisfactory, as demonstrated by the ample and steady supply of steam under all conditions.—"Engineering."

H.M.S. *HAUGHTY.*

H.M.S. *Haughty*, the first of the four torpedo-boat destroyers of the 1912–13 program being built for the British Admiralty by Messrs. Yarrow & Co., Ltd., of Glasgow, was successfully launched on Monday, May 26th.

The *Haughty* is 260 feet long, with a beam of 27 feet 6 inches. The main engines consist of Brown-Curtis turbines, driving two shafts transmitting equal powers, one propeller being fitted on each shaft. Steam is supplied by three of the latest and most improved type of Yarrow boilers, each of which is fitted with Yarrow's patent feed-heating and superheating arrangements, and designed for burning oil fuel exclusively.

FRANCE.

THE FRENCH DREADNOUGHT *JEAN BART*.

The French Dreadnought *Jean Bart* completed her official trials on May 15th last. This vessel was designed in 1909-1910 by Monsieur Lyasse, and the Act authorizing her construction was passed on April 5th of the latter year. Orders to build her were given to the Brest Dockyard authorities on August 5th, and the keel was actually laid on November 10th of the same year. She was launched in September, 1911.

Her leading particulars are: Length, 541 feet 4 inches; beam, 88 feet 8 inches; draught amidships, 29 feet; draught astern, 29 feet 7 inches; designed speed, 20 knots.

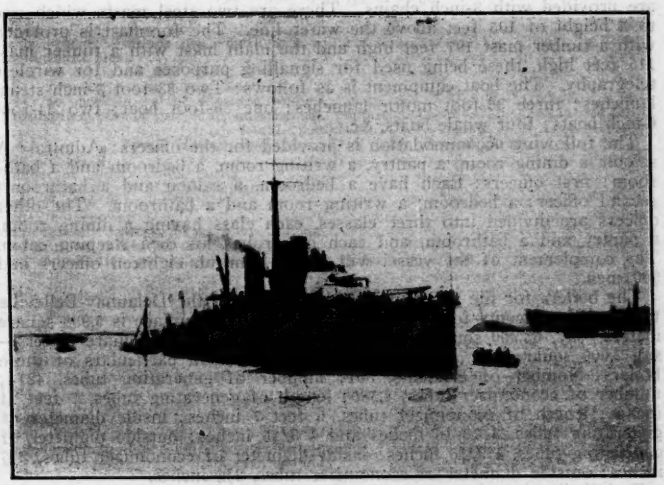
The weight of the hull is given as being 6,500 tons. Siemens steel plates having an average thickness of 20 mm. are employed. There are ten strakes on each side of the keel plates, which latter is made up of two keel plates hydraulically rivetted. The stem is of forged steel, and the stern frame and shaft brackets of cast steel. A double bottom has been worked up to the level of the lower protective deck. There are three docking keels and two bilge keels, the latter being 213 feet in length and 33½ inches deep. There are six decks.

The main armament consists of ten 12-inch guns housed in pairs in five turrets, these being controlled on the Janney electro-hydraulic system. The thickness of the turret armor plating is 10 inches. The guns have been designed to fire one shot each twenty-five seconds. The heights of the guns above the water line varies from 21 feet 5 inches to 30 feet 7 inches, and their arcs of fire from 135 degrees to 180 degrees. Each gun is about 59 feet in length and weighs 55 tons. The shells fired are about 4 feet in length and weigh 970 pounds. One hundred shells per gun are carried.

The secondary armament consists of twenty-two 5½-inch quick firers. These are arranged in ten sections. There are two sections of three guns, one on each side of the citadel, while the remaining guns are arranged in pairs, in casemates. The arc of fire of all these guns is 120 degrees. The guns in the citadel are 18 feet 6 inches above the water line and other guns 12 feet above the same level. The shells each weigh 80 pounds and 275 rounds per gun are carried. The shells are taken up to the casements by electrically-driven hoists which are designed to deliver fifteen shells per minute. There are also four 47 mm.—1.46-guns, and four submerged torpedo tubes. Two of these are arranged forward and two aft. They are of the 1909 design, and are for discharging 18-inch torpedoes. Twelve torpedoes will be carried. Forty Sauter-Harlé submarine mines will also be carried.

The armor belt for a length of 214 feet amidships is 250 mm.—say, 9⅞ inches thick. At the two ends this thickness is reduced to 160 mm.—say, 6⅓ inches. The total depth of the belt is 4.05 m.—say, 13 feet 3 inches—of which 2.35 m.—say, 7 feet 8 inches—are above the water line. The citadel is 197 feet in length, and is protected with 7-inch armor plate, which extends down for two decks. Both ends of the citadel are closed by transverse bulkheads of the same thickness. There are two protective decks. The lower of these is 5 feet 7 inches below the water line, and is composed of 2-inch plating on the flat and 3-inch plating on the slopes. The upper protective deck joins the upper edge of the main armor belt and is composed of 1 13/16-inch plates. This thickness of plating is also employed above the citadel, and for the after casements.

The hull below the lower protective deck is divided into numerous watertight compartments. None of the main compartments are pierced for doorways. For example, there are no doorways cut in the engine-



THE FRENCH BATTLESHIP "JEAN BART."

room bulkheads. The space between the two protective decks is divided into numerous cofferdams and compartments.

The conning tower is protected with plating having a maximum thickness of 12 inches. It is divided into three compartments and access to it is obtained by only one door.

The rudder is of cast steel. It can be operated either by steam, electricity or by hand. It is of the balanced type, and can be turned through an angle of 32 degrees on each side. There are three anchors. Two of these weigh 9 tons each. The other is of the Morel type. All

THE "JEAN BART" ON HER FULL-SPEED TRIAL.

are provided with 3-inch chains. There are two steel masts which rise to a height of 105 feet above the water line. The foremast is provided with a timber mast 197 feet high and the main mast with a timber mast 115 feet high, these being used for signalling purposes and for wireless telegraphy. The boat equipment is as follows: Two 33-foot 3-inch steam launches; three 36-foot motor launches; one 36-foot boat; two 34-foot 6-inch boats; four whale boats, &c.

The following accommodation is provided for the officers: Admiral: A saloon, a dining room, a pantry, a writing room, a bedroom and a bathroom; first officers: Each have a bedroom, a saloon and a bathroom; second officer: a bedroom, a writing room and a bathroom. The other officers are divided into three classes, each class having a dining room, a pantry and a bathroom, and each officer has his own sleeping cabin. The complement of the vessel will be an admiral, eighteen officers and 900 men.

The boilers for the propelling machinery are of the Delaunay-Belleville type, and are twenty-four in number. The heating surface is 5,938 square meters—say, 63,900 square feet; and the grate area 188 square meters—say 2,000 square feet. The following are the main particulars of these boilers: Number of elements, 301; number of generating tubes, 4214; number of economizer tubes, 4,580; length of generating tubes, 7 feet 11 inches; length of economizer tubes, 6 feet 7 inches; inside diameter of generating tubes, 3 15/16 inches and 4 3/16 inches; outside diameter of generating tubes, 4 9/16 inches; inside diameter of economizer tubes, 2½ inches; outside diameter of economizer tubes, 2¾ inches.

Each boiler has four furnaces and may be fired either with coal or oil, Delaunay-Belleville burners being used for the latter. There are three funnels 65 feet high.

There are thirteen coal bunkers having a total capacity of 2,700 tons, and four storage spaces for oil fuel having a total capacity of 300 tons. Under ordinary circumstances only 900 tons of coal will be carried. The radius of action with full bunkers is calculated at 8,500 miles at 10 knots, and 2,300 knots at full speed.

There are two sets of independent Parsons combined-type turbines driving four propellers. They are contained in three independent compartments. The high-pressure turbines each drive a wing shaft, and are each in a separate compartment. The low-pressure turbines, which are in a compartment together, drive the two inner shafts. The high-pressure turbines have four rows of impulse blades and the wheels carrying these are 11 feet 2 inches in diameter. The working speed at full power is given as being 300 revolutions per minute. Live steam can be supplied to the low-pressure turbines, so that the latter can, if required, be run without the wing turbines. The astern turbines have been designed to develop about 40 per cent. of the power of the ahead turbines. The condensers are of the usual type, and are arranged in two compartments aft of the turbine rooms. They have tubes 10 feet in length and are designed to maintain a vacuum of 600 mm.—say, 23.6 inches—with circulating water at 15 degrees C.—say, 59 degrees F. Each condenser has 1,490 square meters—say, 16,000 square feet—of cooling surface.

There are six 200-kilowatt steam dynamos, each driven by a high-speed reciprocating engine. These supply current for power purposes—steering, turret working, shell hoisting, &c.—for lighting and for ten searchlights, eight of which are 35 inches in diameter and two of 30 inches. There are two refrigerating engines and thirteen air coolers. The ammunition rooms are insulated with cork, asbestos, &c. The smokeless-powder rooms are quite distinct from the black-powder rooms, the shell rooms and the guncotton rooms.

The following are the results of the official trials of this vessel:

Ten Hours' Full-speed Trial.

Date	April 29th, 1913.
Number of boilers at work	24
Steam pressure, pounds per square inch	252
Revolutions, mean	285
Speed on measured mile, mean, knots	21.16
for ten hours, mean, knots	21.09
as specified in the contract, knots	20
Consumption of coal per mile, as specified, pounds	2,645
actual, pounds	2,449

Three Hours' Full-speed Trial with Forced Draft.

Date	May 5th.
Number of boilers under steam	24
Steam pressure, pounds per square inch	252
Revolutions	305
Shaft horsepower	42,000
Mean speed, knots	22.04
Best run on measured mile, knots	22.63
Coal consumption, as per contract, for 20 knots per square foot of grate area, pounds	32.77
Ditto, ditto, on actual trial, pounds	30.11
Ditto, ditto, at 22.04 knots, pounds	33.18
Coal per horsepower, as specified, pounds	1.87
actual, pounds	1.7
mile run, pounds	3,167
Air pressure, inches	1.03

Twenty-four Hours' Consumption and Endurance Trial.

Date	May 9th and 10th.
Number of boilers under steam	24
Revolutions	240
Mean speed, knots	18.57
Coal consumption per mile, as specified, pounds	1,840
actual, pounds	1,611

Consumption Trial at Cruising Speed.

Date	May 15th.
Number of boilers under steam	24
Mean speed, knots	12.81
Coal consumption per mile, as specified, pounds	1,080
actual, pounds	937

We understand that the gun trials have also given satisfaction.

THE FRENCH DESTROYER *MAGON*.

On April 19th the French torpedo-boat destroyer *Magon* was launched from the slips of the Ateliers et Chantiers de Bretagne, at Nantes. She belongs to the new class of 800-ton vessels which have been designated "fleet destroyers," and will be, when she is completed, a particularly fine boat. Her stern is shaped not unlike that of a racing motor boat, while she has a high freeboard forward so as to allow her to keep her speed in rough weather.

The main particuars of this destroyer, which was designed by the builders' staff with the assistance of Monsieur Laubœuf, the distinguished naval architect, are as follows: Displacement on trials, 787 tons; displacement with extra bunkers full, 850 tons; length overall, 272 feet 4 inches; breadth, 27 feet; depth, 16 feet 5 inches; draught astern, 10 feet.

The hull, which is of Siemens steel, is divided into eleven watertight compartments. The shell plating has a tensile strength of 38 tons per square inch, with a reduction in area of 16 per cent. The stern is of forged steel, while the stern post, stern brackets, and rudder are of cast steel. The eleven compartments are allotted as follows: The first forward is the collision compartment, then come the chain lockers and store compartments, and then the crew's quarters. Aft of these come two independent boiler rooms, and then two independent engine rooms. Aft of these, again, are the officers' quarters, the petty officers' quarters, and the ammunition and store rooms.

There are to be four water-tube boilers of the du Temple type, which supply steam for the main propelling engines and the auxiliaries. The working pressure is 228 pounds per square inch. They are fired with oil

fuel burnt by du Temple burners. The liquid-fuel tanks have a capacity of 1,300 cubic feet.

The main engines are to be of the Rateau-Chantiers de Bretagne type. There are to be four turbines, two for ahead and two for astern working, and they are to drive two propellers 7 feet 2 inches in diameter. This type of turbine is familiar to our readers and need not again be discussed. According to all accounts, it is giving excellent results in destroyers, while, if rumor is to be believed, it is shortly to be employed for warships of far larger displacement and requiring much greater power than destroyers. The particular turbines in question are designed to give 18,000 shaft horsepower. The contract speed is 30 knots, but a speed of 34 knots is confidently expected.

Two electric sets of 13 kilowatts each, driven by internal-combustion engines, are to supply current at 80 volts for general lighting and for a 24-inch searchlight.

The armament is to consist of four 65 mm. guns on the quarters and one 4-inch gun forward and one aft. Two hundred and fifty shells will be carried for the 4-inch guns and 346 shells for the 65-mm. guns. There will be four 18-inch torpedo tubes, arranged aft in pairs. Six torpedoes will be carried. The complement will be six officers and seventy-five petty officers and men.—"The Engineer."

JAPAN.

THE JAPANESE BATTLE CRUISER *KONGO*.

THE MOST POWERFUL ARMORED CRUISER AFLOAT.

Three new battle cruisers are now being built in Japan—the *Hiyei* at Yokosuka dockyard, the *Haruna* at Kobe, and the *Kirishima* at Nagasaki, while a fourth, the *Kongo*, has recently been completed by Messrs. Vickers, Ltd., at Barrow-in-Furness, and will shortly be delivered. The strategical and tactical qualities governing the design of these four battle cruisers having been enunciated by the Japanese Navy Department from experience gained in the Russo-Japanese war, it was left to this firm to embody the stipulated requirements. The machinery for the first of these battle cruisers has also been constructed by Messrs. Vickers, and she is now in an advanced stage of construction, having been laid down at Yokosuka dockyard on November 4th, 1911, while the others were laid down in March of the following year. The vessels have the following dimensions: Length, 704 feet; breadth, 92 feet; draught, 27 feet 6 inches; displacement, 27,500 tons; service speed, 28 knots; maximum coal capacity, 4,000 tons; oil-fuel capacity, 1,000 tons; shaft horsepower, 70,000; armament, eight 14-inch and sixteen 6-inch guns; torpedoes, six 21-inch submerged

It will, therefore, be gathered that the *Kongo* and her sister ships are practically the same length as the *Princess Royal*, but have each 3 feet 6 inches more beam, and 1,000 tons greater displacement, due to the greater fighting qualities laid down by the Japanese authorities. The armament of the Japanese cruisers comprises eight 14-inch guns, as compared with an equal number of 13.5-inch guns in the British ship, an equal number (sixteen) of guns for repelling torpedo attack, but they are of 6-inch bore as compared with 4-inch in the British ship. The *Kongo* has double the number of submerged torpedo tubes fitted in British ships, and as in these they are designed to fire 21-inch Whitehead torpedoes. Generally the broadside armor corresponds to that in the *Princess Royal*, but, owing to the introduction of armored bulkheads below the water line, a greater weight has been absorbed for protection in the Japanese ship.

The eight 14-inch guns are mounted in pairs in four barbettes, two of which are located forward and two aft, all on the center line. These barbettes are arranged, and the elevation of the gun is fixed, so that four may fire forward and four aft, while all eight may fire on either broadside. Notwithstanding the very powerful armament provided, the armored protection is most effective, particularly against torpedo attack. The main broadside armor is of special quality steel, and is equal in thickness to that of any battle cruiser yet designed, and is carried to the height of the boat deck, which is continued on the same level as the forecastle, forming a citadel, into which the 6-inch gun casemates are worked. The main belt extends considerably below the waterline, and under this again there is an auxiliary armor belt extending some distance below the normal armor shelf. There is a special arrangement of armored bulkheads protecting the vital parts of the ship; the magazines, for instance, being completely surrounded with special steel armor. There is an armored deck at the waterline level, and in addition to this there is an armored deck closing in the ship from stem to stern at the level of the top of the side armor.

The water-tube boilers burn oil fuel as well as coal; the turbines are of the combined impulse and reaction type. To insure safety, the boilers are arranged in eight compartments, four on each side of a center-line bulkhead which extends throughout their entire length, while the coal bunkers are also disposed to afford protection. Again, the engines—two sets of turbines on four shafts—are arranged in two compartments, with a center-line bulkhead between them. The whole of the arrangements preserve the independence of the port and starboard sets of machinery and allow either set to be worked when all parts of the other are disabled. The high-pressure ahead and astern turbines are of the Parsons combined impulse and reaction type.

The full-power trial of eight hours' duration was carried out successfully on May 8th, in stormy weather, a gale blowing most of the time. The designed power and the speed of 28 knots were exceeded.

The gun trials took place on May 14th and 15th. The gun mountings are of the Vickers hydraulic type, but have electric gear for use in the event of the hydraulic system in any way failing. In addition, too, there is a small hydraulic installation for working the guns when they have to be cleaned; but this gear will also serve, instead of manual work, for maneuvering the guns in the event of the main supply of power, either hydraulic or electric, giving out. Another feature of the installation is the application for the first time of the Janney-Williams gear, which proved most reliable and exact in controlling the turret movement, creeping motion or great speed being achieved with equal facility and precision. The most crucial test was the firing of the whole of the 14-inch guns and of all of the 6-inch guns on the starboard beam, making sixteen guns in all. The firing was from the conning-tower and was absolutely instantaneous. It was remarkable that the cascades thrown up by the first contact with the sea of the 100-pound shot from the 6-inch guns were almost simultaneous, suggesting a remarkable uniformity in the trajectory of the guns. The second contact with the water in the case of these shots coincided with the first contact of the 14-inch shot, so that it was not then possible to distinguish between the 100-pound shots and the 1,400-pound shots. The salvo represented a discharge of something over eight tons of metal, with a collective muzzle energy of about 600,000 foot-tons. The effect on the ship was scarcely perceptible, so far as inclination was concerned. No damage was done to the ship's structure, the only damage being to some of the lifeboats, the side planking of which was sprung. The performance was thus in every way an unqualified success, and after the gun trials the ship proceeded to the anchorage at Greenock, whence she left for Barrow-in-Furness on the following day, the torpedo trials being carried out on the way. The *Kongo* is due to leave Barrow for Japan early in August.—"Scientific American."

BOOKS RECEIVED.

SCHIFFSTURBINEN, by DR. G. BAUER and O. LASCHE. Printed by R. OLDENBOURG. Munich and Berlin. 2d Edition. 442 pages, 5½ x 8. Price, 15 Marks.

This work is a supplement to Dr. Bauer's handbook on "Schiffsmachinen und Kessel," first published in 1902. In the first section of Part 1 it deals with the advantages of turbines over reciprocating engines, and in the second section, with the field for marine turbines. Section three enumerates the different systems of marine turbines.

Part 2 gives rules for working out the indicated and effective powers, shows how to find the necessary quantity of steam and the steam consumption of the auxiliaries, the backing power and maneuvering efficiency.

Part 3 treats of the thermodynamics of the turbine and gives, by means of the J. S. diagram, one of the most valuable short cuts for working out all the temperature drops, corresponding pressures, etc. The cross section of the nozzles is also treated in this part, as well as general rules for the calculation and design of steam turbines, comparing them with hydraulic turbines, the composition of velocities, units of work, different types of turbines, the theoretical curves for establishing the efficiency, losses and powers of the different types, and how to find the strength of the blades, and, in fact, the complete design of the different types of turbines.

Part 4 deals with the practical questions of design, such as material, shapes, etc.

Part 5 treats of propellers and shafting and Part 6 of condensers. The remainder of the book, Parts 7 to 14, deals with the different systems of arranging turbines in ships, the types best suited for different conditions, exhaust turbines, reduction gears, turbo-driven auxiliaries, water brakes, care

and preservation of machinery, and a collection of useful tables.

The printing and illustrations are very clear, and the book contains a great amount of useful experimental data and forms a worthy companion to Dr. Bauer's Handbook of Marine Engines and Boilers.

It is hoped that there will soon be an English translation of this edition to enable the American engineers to profit by this work.—A. M. P. M.

TRIP THROUGH GERMANY.—In honor of the recent visit made to Germany by the American Society of Mechanical Engineers upon invitation of the Verein Deutscher Ingenieure, the latter organization has prepared a guide book of 171 pages. This book, which is printed in English and German on facing pages, describes the points of interest in each locality to be visited, laying particular stress, of course, on matters relating to engineering and technical education. The itinerary shows that the American delegates arrived at Hamburg on June 19 and that the official visits and receptions terminated at Munich on July 8.

ASSOCIATION NOTES.

The following members and associates have joined the Society since the publication of the last JOURNAL.

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Theiss, Paul S., Ensign, U. S. Navy.

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